APPENDIX A: UV Rate Constants for Bacteria

Microbe	Type	D_{90} J/m^2	UVGI k m^2/J	Media	RH %	Sh	St	UL J/m^2	Dia. µm	Base Pairs kb	Source (see Chapter 4 Refs)
Acinetobacter baumannii	Veg	18	0.12800	S	-	N	1	90	1.225	3598	Rastogi 2007
Acinetobacter baumannii	Veg	33	0.19200	W	-	Y	2	48	1.225	3598	Templeton 2009
Aeromonas	Veg	11	0.20310	W	Wat	-	-	-	2.098	4740	Sako 1985
Aeromonas hydrophila	Veg	16	0.14100	W	Wat	Y	1	590	2.098	4740	Liltved 1996
B. atrophaeus (B. globigii)	Sp	144	0.01600	Air	(Lo RH)	-	-	-	1.12	4140	EPA 2006
B. atrophaeus spores	Sp	1323	0.00174	W	Wat	N	1	4000	1.12	4140	Shafaat 2006
Bacillus anthracis spores	Sp	411	0.00560	W	Wat	Y	1	600	1.118	5220	Nicholson 2003
Bacillus anthracis spores	Sp	45	0.05094	S	-	N	1	52	1.118	5220	Sharp 1939
Bacillus anthracis spores	Sp	743	0.00310	S	-	Y	2	1890	1.118	5220	Knudson 1986
Bacillus cereus spores	Sp	267	0.00863	S	-	-	-	-	1.118	5700	Weinberger 1984
Bacillus cereus spores	Sp	210	0.01098	S	-	-	-	-	1.118	5700	Weisova 1966
Bacillus cereus spores	Sp	116	0.01979	S	-	-	-	-	1.118	5700	Germaine 1973
Bacillus cereus spores	Sp	408	0.00564	S	-	-	-	-	1.118	5700	Benoit 1990
Bacillus megatherium	Sp	273	0.00843	S	-	-	-	-	1.12	4600	Hercik 1937
Bacillus megatherium	Veg	113	0.02038	S	-	-	-	-	-	4600	Hercik 1937
Bacillus pumilis spores	Sp	50	0.04600	W	Wat	Y	2	100	-	-	New combe 2005
Bacillus subtilis	Veg	25	0.09210	W	Wat	-	-	-	-	4210	Lojo 1995
Bacillus subtilis	Veg	14	0.16858	Air	(Lo RH)	N	1	940	-	4210	Nakamura 1987
Bacillus subtilis spores	Sp	250	0.00920	W	Wat	Y	1	600	1.12	4140	Nicholson 2003
Bacillus subtilis spores	Sp	161	0.01430	W	Wat	N	1	600	1.12	4140	Hoyer 2000
Bacillus subtilis spores	Sp	116	0.01982	W	Wat				1.12	4140	Sommer 1989
Bacillus subtilis spores	Sp	220	0.01047	W	Wat	N	1	500	1.12	4140	Sommer 1998
Bacillus subtilis spores	Sp	199	0.01155	W	Wat	N	1	810	1.12	4140	Sommer 1999
Bacillus subtilis spores	Sp	77	0.03000	W	Wat	Y	1	400	1.12	4140	Qualls 1983
Bacillus subtilis spores	Sp	155	0.01490	W	Wat	Y	1	400	1.12	4140	Mamane-Gravetz 2005
Bacillus subtilis spores	Sp	89	0.02580	W	Wat	-	-	-	1.12	4140	Horneck 1985
Bacillus subtilis spores	Sp	200	0.01150	W	Wat	Y	2	800	1.12	4140	Chang 1985
Bacillus subtilis spores	Sp	80	0.02880	W	Wat	Y	2	400	1.12	4140	DeGuchi 2005
Bacillus subtilis spores	Sp	94	0.02460	S	-	-	-	220	1.12	4140	Rentschler 1941
Bacillus subtilis spores	Sp	68	0.03370	S	-	-	-	-	1.12	4140	Munakata 1975
Bacillus subtilis spores	Sp	113	0.02030	S	-	-	-	-	1.12	4140	Munakata 1972
Bacillus subtilis spores	Sp	89	0.02600	Air	Hi RH	N	1	45.0	1.12	4140	Peccia 2001a
Bacillus subtilis spores	Sp	149	0.01550	Air	Lo RH	Y	1	550	1.12	4140	Ke 2009
Bacillus subtilis spores	Sp	85	0.02700	Air	Lo RH	N	1	45.0	1.12	4140	Peccia 2001a
Bacillus thuringiensis	Sp	2303	0.00100	W	Wat	N	2	10000	-	-	Griego 1978
Burkholderia cenocepacia	Veg	58	0.03956	W	Wat	N	1	60	0.707	7270	Abshire 1981
Burkholderia cepacia	Veg	11	0.21150	Air	Lo RH	N	1	23	0.77	7700	Fletcher 2004
Burkholderia cepacia	Veg	22	0.10520	Air	Hi RH	N	1	23	0.77	7700	Fletcher 2004
Campylobacter jejuni	Veg	11	0.20933	W	Wat	-	-	-	2.12	1641	Wilson 1992
Campylobacter jejuni	Veg	29	0.07940	W	Wat	-	-	-	2.12	1641	Butler 1987
Citrobacter diversus	Veg	32	0.07140	W	Wat	N	1	130	1.2	-	Giese 2000
Citrobacter freundii	Veg	42	0.05482	W	Wat	-	-	-	1.2	-	Zemke 1990
Citrobacter freundii	Veg	46	0.05010	W	Wat	N	1	130	1.2	-	Giese 2000
Clostridium perfringens	Veg	38	0.06000	W	Wat	-	-	-	5	3031	Hijnen 2006
Clostridium perfringens	Veg	135	0.01700	-	-	-	-	-	5	3031	Jepson 1973
Clostridium tetani	Veg	49	0.04699	-	-	-	-	-	5	2790	Jepson 1973
Corynebacterium diphtheriae	Veg	33	0.07010	S	-	N	1	46	0.698	2480	Sharp 1939
Coxiella burnetii	Veg	15	0.15350	W	Wat	-	-	-	0.283	2030	Little 1980
Deinococcus radiodurans	Veg	365	0.00630	W	Wat	Y	1	1200	-	3280	Setlow 1964
Enterobacter cloacae	Veg	64	0.03598	W	Wat	-	-	-	1.414	-	Zemke 1990
Escherichia coli	Veg	21	0.10900	W	Wat	N	1	21	0.5	5490	Zelle 1955
Escherichia coli	Veg	53	0.04320	W	Wat	N	1	24	0.5	5490	Tyrrell 1972
Escherichia coli	Veg	20	0.11510	W	Wat	N	1	60	0.5	5490	Oguma 2001
Escherichia coli	Veg	47	0.04940	W	Wat	N	1	900	0.5	5490	Kim 2002
Escherichia coli	Veg	43	0.05300	W	Wat	Y	1	60	0.5	5490	Hofemeister 1975
Escherichia coli	Veg	13	0.18000	W	Wat	Y	2	-	0.5	5490	Harris 1987
Escherichia coli	Veg	20	0.11500	W	Wat	Y	1	120	0.5	5490	Harm 1968
Escherichia coli	Veg	24	0.09600	W	Wat	Y	1	200	0.5	5490	David 1973
Escherichia coli	Veg	81	0.02832	W	Wat	N	1	83	0.5	5490	Abshire 1981
Escherichia coli	Veg	25	0.09398	S	-	N	1	45	0.5	5490	Sharp 1939
Escherichia coli	Veg	19	0.12000	S	Hi RH	N	1	4.4	0.5	5490	Rentschler 1942
Escherichia coli	Veg	12	0.19300	S	Lo RH	N	1	4.4	0.5	5490	Rentschler 1942
Escherichia coli	Veg	25	0.09210	S	-			22	0.5	5490	Rentschler 1941

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Microbe	Type	D_{90} J/m^2	UVGI k m^2/J	Media	RH %	Sh	St	UL J/m^2	Dia. µm	Base Pairs kb	Source (see Chapter 4 Refs)
Escherichia coli	Veg	20	0.11670	S	-	Y	1	130	0.5	5490	Quek 2008
Escherichia coli	Veg	51	0.04540	S	-	N	1	66	0.5	5490	Luckiesh 1949
Escherichia coli	Veg	34	0.06720	S	-	N	1	900	0.5	5490	Kim 2002
Escherichia coli	Veg	55	0.04187	S	-	-	-	-	0.5	5490	Hollaender 1955
Escherichia coli	Veg	8	0.28300	S	-	N	1	48	0.5	5490	Collins 1971
Escherichia coli	Veg	3	0.72300	Air	Lo RH	-	-	6	0.5	5490	Webb 1970
Escherichia coli	Veg	11	0.21800	Air	Hi RH	-	-	6	0.5	5490	Webb 1970
Escherichia coli	Veg	11	0.21900	Air	Hi RH	N	1	4.4	0.5	5490	Rentschler 1942
Escherichia coli	Veg	13	0.18100	Air	Lo RH	N	1	4.4	0.5	5490	Rentschler 1942
Escherichia coli	Veg	15	0.15611	Air	Lo RH	N	2	4	0.5	5490	Luckiesh 1949
Escherichia coli	Veg	2	0.96500	Air	Lo RH	N	1	0.5	0.5	5490	Koller 1939
Escherichia coli	Veg	11	0.20500	Air	Hi RH	N	1	0.5	0.5	5490	Koller 1939
Francisella tularensis	Veg	256	0.00900	Air	Lo RH	N	1	1	0.2	1890	Beebe 1959
Francisella tularensis	Veg	288	0.00800	Air	Hi RH	N	1	1	0.2	1890	Beebe 1959
Haemophilus influenzae	Veg	38	0.05990	S	-	Y	2	16	0.285	1910	Mongold 1992
Haemophilus influenzae Rd	Veg	13	0.17700	W	Wat	N	2	55	0.285	1910	Barnhart 1970
Halobacterium sp. NRC-1	Veg	25	0.09210	S	-	N	1	150	-	2571	Crow ley 2006
Halobacterium salinarum	Veg	68	0.03390	-	-	N	1	200	-	-	Martin 2000
Halomonas elongata	Veg	13	0.18090	-	-	N	1	10	-	-	Martin 2000
Helicobacter pylori	Veg	33	0.06900	W	Wat	N	1	80	2.1	1780	Hayes 2006
Klebsiella pneumoniae	Veg	42	0.05480	W	Wat	-	-	-	0.671	5315	Zemke 1990
Klebsiella pneumoniae	Veg	68	0.03390	W	Wat	N	1	200	0.671	5315	Giese 2000
Klebsiella terrigena	Veg	33	0.07000	W	Wat	N	1	110	-	-	Wilson 1992
Legionella dumoffi	Veg	24	0.09594	S	-	N	1	72	0.52	3400	Knudson 1985
Legionella bozemanii	Veg	19	0.17400	W	Wat	Y	1	97	0.52	3400	Yamamoto 1987
Legionella bozemanii	Veg	15	0.15351	S	-	N	2	72	0.52	3400	Knudson 1985
Legionella gormanii	Veg	26	0.08856	S	-	N	1	72	0.52	3400	Knudson 1985
Legionella jordanis	Veg	11	0.20933	S	-	N	1	72	0.52	3400	Knudson 1985
Legionella longbeach	Veg	11	0.20933	S	-	N	1	72	0.52	3400	Knudson 1985
Legionella micdadei	Veg	15	0.15351	S	-	N	1	72	0.52	3400	Knudson 1985
Legionella oakridgensis	Veg	22	0.10466	S	-	N	1	72	0.52	3400	Knudson 1985
Legionella pneumophila	Veg	13	0.17400	W	Wat	Y	1	97	0.52	3400	Yamamoto 1987
Legionella pneumophila	Veg	12	0.19298	W	Wat	Y	1	0.5	0.52	3400	Gilpin 1985
Legionella pneumophila	Veg	9	0.24849	W	Wat	N	1	30	0.52	3400	Antopol 1979
Legionella pneumophila	Veg	5	0.44613	S	-	N	2	72	0.52	3400	Knudson 1985
Legionella pneumophila	Veg	25	0.09110	W	Wat	N	1	72	0.52	3400	Wilson 1992
Legionella pneumophila	Veg	16	0.14390	W	Wat	N	1	80	0.52	3400	Oguma 2004 (LP)
Legionella pneumophila	Veg	19	0.12020	W	Wat	N	1	96	0.52	3400	Oguma 2004 (MP)
Legionella wadsworthii	Veg	4	0.57565	S	-	N	2	72	0.52	3400	Knudson 1985
Listeria monocytogenes	Veg	181	0.01270	W	Wat	N	1	900	0.707	3130	Kim 2002
Listeria monocytogenes	Veg	156	0.01480	S	-	N	1	900	0.707	3130	Kim 2002
Listeria monocytogenes	Veg	10	0.23030	S	-	Y	1	48	0.707	3130	Collins 1971
Micrococcus candidus	Veg	61	0.03806	S	-	-	-	-	1.2	4050	Hollaender 1955
Micrococcus piltonensis	Veg	81	0.02843	S	-	-	-	132	2.2	-	Rentschler 1941
Micrococcus sphaeroides	Veg	100	0.02303	S	-	-	-	154	1.2	4050	Rentschler 1941
Moraxella	Veg	10965	0.00022	W	Wat	N	1	5940	1.225	1940	Keller 1982
Mycobacterium avium-intra.	Veg	84	0.02740	W	Wat	Y	1	200	1.118	5470	David 1973
Mycobacterium avium	Veg	60	0.03840	W	Wat	Y	1	20	1.118	5470	Shin 2008
Mycobacterium avium	Veg	35	0.06580	W	Wat	-	-	-	1.118	5470	McCarthy 1974
Mycobacterium bovis BCG	Veg	22	0.10550	S	-	N	1	48	0.637	4340	Collins 1971
Mycobacterium bovis BCG	Veg	10	0.24200	Air	50	N	1	5.0	0.637	4340	Riley 1976
Mycobacterium bovis BCG	Veg	12	0.19000	Air	-	-	-	-	0.637	4340	Peccia 2002
Mycobacterium bovis BCG	Veg	19	0.12000	Air	Lo RH	N	1	8.3	0.637	4340	Ko 2000
Mycobacterium bovis BCG	Veg	33	0.07000	Air	Hi RH	N	1	8.3	0.637	4340	Ko 2000
Mycobacterium flaviscens	Veg	120	0.01919	W	Wat	Y	1	200	0.637	-	David 1973
Mycobacterium fortuitum	Veg	68	0.03390	W	Wat	Y	1	200	0.637	5000	David 1973
Mycobacterium fortuitum	Veg	96	0.02400	W	Wat	Y	1	891	0.637	5000	David 1971
Mycobacterium kansasii	Veg	80	0.02880	W	Wat	Y	1	200	0.637	4345	David 1973
Mycobacterium marinum	Veg	76	0.03030	W	Wat	Y	1	200	0.637	6485	David 1973
Mycobacterium marinum	Veg	743	0.00310	W	Wat	Y	1	1782	0.637	6485	David 1971
Mycobacterium parafortuitum	Veg	13	0.18000	Air	50	N	1	45.0	0.637	-	Peccia 2001
Mycobacterium parafortuitum	Veg	46	0.05000	Air	95	N	1	45.0	0.637	-	Peccia 2001
Mycobacterium parafortuitum	Veg	19	0.12000	Air	50	N	1	-	0.637	-	Xu 2003

APPENDIX A: UV Rate Constants for Bacteria

Microbe	Type	D_{90} J/m^2	UVGI k m^2/J	Media	RH %	Sh	St	UL J/m^2	Dia. µm	Base Pairs kb	Source (see Chapter 4 Refs)
Mycobacterium phlei	Veg	76	0.03030	W	Wat	Y	1	200	0.637	6000	David 1973
Mycobacterium phlei	Veg	63	0.03650	Air	50	N	1	5.0	0.637	6000	Riley 1976
Mycobacterium phlei	Veg	23	0.10000	Air	50	-	-	-	0.637	6000	Kethley 1973
Mycobacterium phlei	Veg	16	0.14000	Air	50	-	-	-	0.637	6000	Gillis 1974
Mycobacterium smegmatis	Veg	108	0.02130	W	Wat	Y	1	200	0.637	6980	David 1973
Mycobacterium smegmatis	Veg	1047	0.00220	W	Wat	Y	1	2430	0.637	6980	David 1971
Mycobacterium smegmatis	Veg	68	0.03400	W	Wat	Y	2	500	0.637	6980	Boshoff 2003
Mycobacterium smegmatis	Veg	12	0.19000	Air	50	-	-	-	0.637	6980	Gillis 1974
Mycobacterium terrae	Veg	50	0.04610	W	Wat	N	1	100	0.637	-	Bohrerova 2006
Mycobacterium tuberculosis	Veg	28	0.08220	W	Wat	Y	1	200	0.637	4400	David 1973
Mycobacterium tuberculosis	Veg	77	0.03000	W	Wat	Y	1	567	0.637	4400	David 1971
Mycobacterium tuberculosis	Veg	74	0.03100	W	Wat	Y	2	500	0.637	4400	Boshoff 2003
Mycobacterium tuberculosis	Veg	11	0.21320	S	-	N	1	48	0.637	4400	Collins 1971
Mycobacterium tuberculosis	Veg	5	0.47210	Air	50	N	1	5.0	0.637	4400	Riley 1976
Mycoplasma arthritidis	Veg	7	0.31240	S	-	Y	1	22	0.177	816	Furness 1977
Mycoplasma fermentans	Veg	9	0.25220	S	-	Y	1	22	0.177	816	Furness 1977
Mycoplasma hominis	Veg	7	0.32710	S	-	Y	1	22	0.177	816	Furness 1977
Mycoplasma Orale type 1	Veg	11	0.21800	S	-	Y	1	22	0.177	816	Furness 1977
Mycoplasma Orale type 2	Veg	6	0.38760	S	-	Y	1	22	0.177	816	Furness 1977
Mycoplasma pneumoniae	Veg	8	0.27910	S	-	Y	1	22	0.177	816	Furness 1977
Mycoplasma salivarium	Veg	11	0.21140	S	-	Y	1	22	0.177	816	Furness 1977
Myxobolus cerebralis	Veg	10011	0.00023	W		Y	2	10000	-	-	Hedrick 2000
Neisseria catarrhalis	Veg	44	0.05233	S	-	-	-	121	0.177	816	Rentschler 1941
Nocardia asteroides	Veg	280	0.00822	S	-	-	-	280	1.118	6021	Chick 1963
Phytomonas tumefaciens	Veg	44	0.05233	S	-	-	-	110	-	-	Rentschler 1941
Proteus mirabilis	Veg	8	0.28900	W	Wat	N	1	60	0.494	4063	Hofemeister 1975
Proteus vulgaris	Veg	30	0.07675	S	-			70	0.291	3462	Rentschler 1941
Pseudomonas aeruginosa	Veg	10	0.22692	W	Wat	Y	1	0.4	0.494	5900	Gilpin 1985
Pseudomonas aeruginosa	Veg	172	0.01340	W	Wat	N	2	770	0.494	5900	Dolman 1989
Pseudomonas aeruginosa	Veg	36	0.06600	W	Wat	N	1	340	0.494	5900	Abshire 1981
Pseudomonas aeruginosa	Veg	55	0.04190	W	Wat	N	1	55	0.494	5900	Zelle 1955
Pseudomonas aeruginosa	Veg	55	0.04187	S	-	-	-	-	0.494	5900	Hollaender 1955
Pseudomonas aeruginosa	Veg	22	0.10470	S	-	N	1	20	0.494	5900	Elasri 1999
Pseudomonas aeruginosa	Veg	10	0.23750	S	-	N	2	48	0.494	5900	Collins 1971
Pseudomonas aeruginosa	Veg	4	0.57210	Air	(Lo RH)	N	1	248	0.494	5900	Sharp 1940
Pseudomonas diminuta	Veg	96	0.02391	W	Wat	N	1	118	0.5	-	Abshire 1981
Pseudomonas fluorescens	Veg	35	0.06579	S	-	-	-	70	0.5	6438	Rentschler 1941
Pseudomonas fluorescens	Veg	3	0.47730	Air	50	N	1	13	0.5	6438	vanOsdell 2002
Pseudomonas maltophilia	Veg	70	0.03294	W	Wat	N	1	71	0.5	-	Abshire 1981
Pseudomonas putrefaciens	Veg	87	0.02662	W	Wat	N	1	89	0.5	-	Abshire 1981
Rickettsia prowazekii	Veg	13	0.17600	W	Wat	N	2	6700	0.6	1110	Allen 1954
Salmonella spp.	Veg	11	0.21380	W	Wat	N	2	20	0.8	4746	Yaun 2003
Salmonella anatum	Veg	60	0.03840	W	Wat	N	1	150	0.8	-	Tosa 1998
Salmonella derby	Veg	36	0.06360	W	Wat	N	1	75	0.8	-	Tosa 1998
Salmonella enteritidis	Veg	10	0.22100	S	-	N	1	48	0.8	4746	Collins 1971
Salmonella enteritidis	Veg	33	0.07010	W	Wat	N	1	100	0.8	4746	Tosa 1998
Salmonella infantis	Veg	20	0.11510	W	Wat	N	1	60	0.8	-	Tosa 1998
Salmonella typhi	Veg	21	0.10760	W	Wat	N	1	21	0.806	4791	Zelle 1955
Salmonella typhi	Veg	30	0.07675	W	Wat	Y	1	100	0.806	4791	Chang 1985
Salmonella typhi	Veg	21	0.10760	S	-	N	1	40	0.806	4791	Sharp 1939
Salmonella typhi	Veg	9	0.25580	W	Wat	N	2	18	0.806	4791	Wilson 1992
Salmonella typhimurium	Veg	295	0.00780	W	Wat	N	1	900	0.8	4950	Kim 2002
Salmonella typhimurium	Veg	18	0.12830	W	Wat	N	2	50	0.8	-	Tosa 1998
Sarcina lutea	Veg	197	0.01169	S	-	-	-	264	1.48	-	Rentschler 1941
Serratia indica	Veg	209	0.01100	Air	42-51	N	1	370	0.632	-	Harstad 1954
Serratia marcescens	Veg	22	0.10490	W	Wat	N	1	22	0.632	5114	Zelle 1955
Serratia marcescens	Veg	105	0.02194	W	Wat	-	-	-	0.632	5114	Harris 1993
Serratia marcescens	Veg	22	0.10470	S	-	N	1	39	0.632	5114	Sharp 1939
Serratia marcescens	Veg	22	0.10466	S	-	-	-	70	0.632	5114	Rentschler 1941
Serratia marcescens	Veg	8	0.27742	S	-	-	-	-	0.632	5114	Hollaender 1955
Serratia marcescens	Veg	10	0.22080	S	-	N	1	48	0.632	5114	Collins 1971
Serratia marcescens	Veg	2	0.93900	Air	Lo RH	Y	2	40	0.632	5114	Fletcher 2003
Serratia marcescens	Veg	24	0.09500	Air	Hi RH	Y	2	40	0.632	5114	Fletcher 2003

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Microbe	Type	D_{90} J/m^2	UVGI k m^2/J	Media	RH %	Sh	St	UL J/m^2	Dia. µm	Base Pairs kb	Source (see Chapter 4 Refs)
Serratia marcescens	Veg	8	0.28670	Air	25-57	N	1	31	0.632	5114	UVDI 2001
Serratia marcescens	Veg	4	0.57500	Air	22-33	N	1	8.3	0.632	5114	Ko 2000
Serratia marcescens	Veg	115	0.02000	Air	Hi RH	N	1	8.3	0.632	5114	Ko 2000
Serratia marcescens	Veg	5	0.44490	Air	(Lo RH)	Y	1	248	0.632	5114	Sharp 1940
Serratia marcescens	Veg	20	0.11300	Air	(Lo RH)	Y	1	940	0.632	5114	Nakamura 1987
Serratia marcescens	Veg	33	0.07000	Air	95	N	1	45.0	0.632	5114	Peccia 2001
Serratia marcescens	Veg	3	0.92000	Air	68	N	1	2	0.632	5114	Lai 2004
Serratia marcescens	Veg	3	0.43050	Air	50	N	1	13	0.632	5114	vanOsdell 2002
Serratia marcescens	Veg	5	0.45000	Air	50	N	1	45.0	0.632	5114	Peccia 2001
Serratia marcescens	Veg	1	2.20000	Air	36	N	1	2	0.632	5114	Lai 2004
Shigella dysenteriae	Veg	18	0.13080	W	Wat	-	-	-	0.801	4369	Wilson 1992
Shigella paradysenteriae	Veg	17	0.13706	S	-	N	1	40	0.801	-	Sharp 1939
Shigella sonnei	Veg	18	0.12500	W	Wat	Y	1	100	0.801	-	Chang 1985
Spirillum rubrum	Veg	44	0.05233	S	-	-	-	88	-	-	Rentschler 1941
Staphylococcus albus	Veg	18	0.12514	S	-	Y	1	25	1.06	2900	Sharp 1939
Staphylococcus albus	Veg	33	0.06978	S	-	-	-	62	1.06	2900	Rentschler 1941
Staphylococcus albus (1)	Veg	23	0.09950	Air	(Lo RH)	N	1	4.4	1.06	2900	Rentschler 1942
Staphylococcus albus (2)	Veg	52	0.04400	Air	(Lo RH)	N	1	4.4	1.06	2900	Rentschler 1942
Staphylococcus aureus	Veg	52	0.04400	W	Wat	N	2	770	0.866	2800	Dolman 1989
Staphylococcus aureus	Veg	27	0.08531	W	Wat	Y	2	150	0.866	2800	Chang 1985
Staphylococcus aureus	Veg	56	0.04134	W	Wat	N	1	58	0.866	2800	Abshire 1981
Staphylococcus aureus	Veg	30	0.07700	S	-	N	1	4	0.866	2800	Sturm 1932
Staphylococcus aureus	Veg	50	0.04652	S	-	-	-	-	0.866	2800	Hollaender 1955
Staphylococcus aureus	Veg	66	0.03500	S	-	N	1	30	0.866	2800	Gates 1934
Staphylococcus aureus	Veg	26	0.08860	S	-	N	1	35	0.866	2800	Sharp 1939
Staphylococcus aureus	Veg	37	0.06240	S	-	N	1	48	0.866	2800	Luckiesh 1949
Staphylococcus aureus	Veg	19	0.11840	S	-	N	2	33	0.866	2800	Gates 1929
Staphylococcus aureus	Veg	20	0.11300	Air	(Lo RH)	N	1	940	0.866	2800	Nakamura 1987
Staphylococcus aureus	Veg	7	0.34760	Air	(Lo RH)	N	1	248	0.866	2800	Sharp 1940
Staphylococcus aureus	Veg	2	0.96020	Air	-	N	2	3	0.866	2800	Luckiesh 1949
Staphylococcus aureus	Veg	2	0.96200	Air	(Lo RH)	-	-	-	0.866	2800	Luckiesh 1946
Staphylococcus epidermis	Veg	161	0.01433	W	Wat	-	-	-	0.866	2640	Harris 1993
Staphylococcus epidermis	Veg	14	0.16210	Air	50	N	1	10	0.866	2640	vanOsdell 2002
Staphylococcus epidermis	Veg	29	0.00800	Air	85	N	1	10	0.866	2640	vanOsdell 2002
Staphylococcus epidermis	Veg	20	0.11300	Air	(Lo RH)	N	1	940	0.866	2640	Nakamura 1987
Staphylococcus epidermis	Veg	22	0.10500	Air	(Lo RH)	N	1	56	0.866	2640	Furuhashi 1989
Streptococcus agalactiae	Veg	5	0.43420	Air	-	N	2	7	0.707	2127	Luckiesh 1949
Streptococcus faecalis	Veg	55	0.09200	W	Wat	Y	2	150	0.707	-	Chang 1985
Streptococcus faecalis	Veg	195	0.01180	W	Wat	N	2	500	0.707	-	Sanz 2007
Streptococcus faecalis	Veg	31	0.07540	W	Wat	Y	2	150	0.707	-	Harris 1987
Streptococcus faecalis	Veg	120	0.01919	W	Wat	N	1	121	0.707	-	Abshire 1981
Streptococcus faecium	Veg	45	0.05100	W	Wat	N	1	350	0.632	5114	Martiny 1988
Streptococcus haemolyticus	Veg	22	0.10660	S	-	N	1	35	0.707	2680	Sharp 1939
Streptococcus lactis	Veg	62	0.03744	S	-	-	-	88	0.707	-	Rentschler 1941
Streptococcus pneumoniae	Veg	468	0.00492	S	-	-	1	3000	0.707	-	Gritz 1990
Streptococcus pyogenes	Veg	4	0.06161	S	-	N	2	94	0.894	1900	Lidw ell 1950
Streptococcus pyogenes	Veg	1	1.56100	Air	-	N	2	2	0.894	1900	Luckiesh 1949
Streptococcus viridans	Veg	20	0.11513	S	-	N	1	32	0.707	-	Sharp 1939
Streptomyces coelicolor	Veg	60	0.03840	W	Wat	N	1	120	-	8667	Jagger 1970
Streptomyces griseus	Veg	129	0.01780	W	Wat	N	1	672	-	8545	Kelner 1949
Streptomyces griseus	Veg	60	0.03840	W	Wat	N	1	120	-	8545	Jagger 1970
Vibrio anguillarum (fish)	Veg	10	0.23820	W	Wat	-	-	-	2.12	-	Sako 1985
Vibrio anguillarum (fish)	Veg	5	0.42600	W	Wat	N	2	27	2.12	-	Liltved 1995
Vibrio cholerae	Veg	17	0.13400	W	Wat	-	-	-	2.12	4148	Wilson 1992
Vibrio ordalii	Veg	18	0.12560	W	Wat	-	-	-	2.12	-	Sako 1985
Vibrio parahaemolyticus	Veg	8	0.30700	W	Wat	N	1	30	2.12	5165	Nozu 1977
Vibrio salmonicida (fish)	Veg	5	0.42600	W	Wat	N	2	27	-	-	Liltved 1995
Yersinia enterocolitica	Veg	15	0.15351	W	Wat	-	-	-	0.707	4615	Butler 1987
Yersinia enterocolitica	Veg	28	0.08127	W	Wat	-	-	-	0.707	4615	Carlson 1975
Yersinia enterocolitica	Veg	11	0.20467	W	Wat	-	-	-	0.707	4615	Butler 1987
Yersinia enterocolitica	Veg	13	0.17170	W	Wat	N	1	46	0.707	4615	Wilson 1992
Yersinia ruckeri (fish)	Veg	5	0.42600	W	Wat	N	2	-	-	-	Liltved 1995
Yersinia ruckeri (fish)	Veg	10	0.23020	W	Wat	N	2	30	-	-	Liltved 1996

APPENDIX B: UV Rate Constants for Viruses

Microbe	Type	D_{90} J/m^2	UVGI k m^2/J	Media	RH %	Sh	St	UL J/m^2	Dia. µm	Base Pairs kb	Source (see Chapter 4 Refs)
Adenovirus	dsDNA	34	0.06800	Air	Hi RH	N	1	26	0.079	35.937	Walker 2007
Adenovirus	dsDNA	59	0.03900	Air	Lo RH	N	1	26	0.079	35.937	Walker 2007
Adenovirus	dsDNA	42	0.05500	Air	50	N	1	68	0.079	36.001	Jensen 1964
Adenovirus	dsDNA	903	0.00255	W	Wat	N	1	900	0.079	36.001	Wasserman 1962
Adenovirus type 1	dsDNA	299	0.00770	W	Wat	-	-	300	0.079	36.001	Battiggelli 1993
Adenovirus type 1	dsDNA	350	0.00658	W	Wat	N	1	1200	0.079	36.001	Nwachuku 2005
Adenovirus type 2	dsDNA	400	0.00576	S	-	N	1	1200	0.079	35.937	Day 1974
Adenovirus type 2	dsDNA	640	0.00360	W	Wat	N	1	480	0.079	35.937	Rainbow 1970
Adenovirus type 2	dsDNA	490	0.00470	W	Wat	N	2	400	0.079	36.001	Rainbow 1973
Adenovirus type 2	dsDNA	533	0.00432	W	Wat	N	1	1200	0.079	35.937	Linden 2007 (LP lamp)
Adenovirus type 2	dsDNA	150	0.01540	W	Wat	N	1	1200	0.079	35.937	Linden 2007 (MP lamp)
Adenovirus type 2	dsDNA	300	0.00768	W	Wat	N	1	60	0.079	35.937	Shin 2005
Adenovirus type 2	dsDNA	400	0.00576	W	Wat	N	1	3000	0.079	35.937	Gerba 2002
Adenovirus type 2	dsDNA	276	0.00834	W	Wat	N	1	1000	0.079	35.937	Ballester 2004
Adenovirus type 4	dsDNA	921	0.00250	W	Wat	N	1	1200	0.079	35.937	Nwachuku 2005
Adenovirus type 15	dsDNA	396	0.00581	W	Wat	N	1	2100	0.079	35.937	Thompson 2003
Adenovirus type 40	dsDNA	300	0.00768	S	-	N	1	1240	0.069	36.001	Meng 1996
Adenovirus type 40	dsDNA	546	0.00422	W	Wat	N	1	200	0.069	36.001	Thurston-Enriquez 2003
Adenovirus type 41	dsDNA	240	0.00976	S	-	N	1	1118	0.069	36.001	Meng 1996
Adenovirus type 41	dsDNA	425	0.00542	W	Wat	-	-	-	0.069	36.001	Malley 2004
Adenovirus type 41	dsDNA	555	0.00415	W	Wat	N	1	300	0.069	36.001	Ko 2005
Adenovirus type 41	dsDNA	600	0.00384	W	Wat	N	1	12	0.069	36.001	Durance 2005
Adenovirus type 5	dsDNA	400	0.00576	W	Wat	N	1	12	0.084	35.938	Durance 2005
Adenovirus type 5	dsDNA	541	0.00426	W	Wat	N	1	2160	0.084	36.598	Wang 2004
Adenovirus type 5	dsDNA	720	0.00320	W	Wat	N	1	1200	0.084	35.598	Nwachuku 2005
Adenovirus type 6	dsDNA	390	0.00590	W	Wat	N	1	1200	0.079	35.937	Nwachuku 2005
Adenovirus type 6	dsDNA	400	0.00576	W	Wat	-	-	-	0.079	35.937	Battiggelli 1993
AHNV (fish virus)	ssRNA	349	0.00660	W	Wat	-	-	-	-	-	Liltved 2005
Avian Influenza virus	ssRNA	22	0.10600	W	Wat	N	2	97	0.09	-	Lucio-Forster 2006
Avian Influenza virus	ssRNA	30	0.07680	W	Wat	-	-	-	0.098	-	Deshmukh 1968
Avian Leukosis virus (RSA)	ssRNA	631	0.00365	W	Wat	N	1	1620	0.107	7.286	Levinson 1966
Avian Sarcoma virus	ssDNA	155	0.01490	W	Wat	N	1	372	0.098	7	Owada 1976
Avian Sarcoma virus	ssDNA	381	0.00604	W	Wat	N	1	768	0.098	7	Bister 1977
B. subtilis phage 029	dsDNA	70	0.03289	W	Wat	-	-	-	-	-	Freeman 1987
B. subtilis phage SP02c12	dsDNA	100	0.02303	W	Wat	-	-	-	0.087	44.01	Freeman 1987
B. subtilis phage SPP1	dsDNA	195	0.01181	W	Wat	-	-	-	0.087	44.01	Freeman 1987
Bacteriophage B40-8	dsDNA	137	0.01679	W	Wat	Y	1	400	-	-	Sommer 2001
Bacteriophage F-specific	dsRNA	292	0.00789	W	Wat	N	1	300	0.025	-	Havelaar 1987
Bacteriophage MS2	ssRNA	26	0.04800	Air	Hi RH	N	1	26	0.02	3.569	Walker 2007
Bacteriophage MS2	ssRNA	61	0.03800	Air	Lo RH	N	1	26	0.02	3.569	Walker 2007
Bacteriophage MS2	ssRNA	3	0.81000	Air	Lo RH	N	1	12	0.02	3.569	Tseng 2005
Bacteriophage MS2	ssRNA	4	0.64000	Air	Hi RH	N	1	12	0.02	3.569	Tseng 2005
Bacteriophage MS2	ssRNA	606	0.00380	W	Wat	N	1	110	0.02	3.569	Furuse 1971
Bacteriophage MS2	ssRNA	135	0.01710	W	Wat	N	1	301	0.02	3.569	Tree 1997
Bacteriophage MS2	ssRNA	427	0.00539	W	Wat	N	1	600	0.02	3.569	Sommer 2001
Bacteriophage MS2	ssRNA	193	0.01190	W	Wat	N	1	360	0.02	3.569	Sommer 1998
Bacteriophage MS2	ssRNA	419	0.00550	W	Wat	Y	1	600	0.02	3.569	Mamane-Gravetz 2005
Bacteriophage MS2	ssRNA	368	0.00625	W	Wat	N	1	600	0.02	3.569	Templeton 2006
Bacteriophage MS2	ssRNA	295	0.00780	W	Wat	N	1	201	0.02	3.569	Ko 2005
Bacteriophage MS2	ssRNA	40	0.05760	W	Wat	N	2	40	0.02	3.569	Weidenmann 1993
Bacteriophage MS2	ssRNA	173	0.01330	W	Wat	N	1	1090	0.02	3.569	Wilson 1992
Bacteriophage MS2	ssRNA	275	0.00837	W	Wat	N	1	200	0.02	3.569	Thurston-Enriquez 2003
Bacteriophage MS2	ssRNA	217	0.01060	W	Wat	N	1	920	0.02	3.569	Batch 2004
Bacteriophage MS2	ssRNA	250	0.00920	W	Wat	N	1	250	0.02	3.569	Battiggelli 1993
Bacteriophage MS2	ssRNA	217	0.01060	W	Wat	N	1	1500	0.02	3.569	Simonet 2006
Bacteriophage MS2	ssRNA	217	0.01063	W	Wat	N	1	800	0.02	3.569	deRodaHusman 2004
Bacteriophage MS2	ssRNA	213	0.01080	W	Wat	N	1	400	0.02	3.569	Butkus 2004
Bacteriophage MS2	ssRNA	187	0.01230	W	Wat	-	-	-	0.02	3.569	Oppenheimer 1997
Bacteriophage MS2	ssRNA	169	0.01360	W	Wat	N	1	800	0.02	3.569	Nuanualsuwan 2002
Bacteriophage MS2	ssRNA	164	0.01402	W	Wat	N	1	900	0.02	3.569	Rauth 1965
Bacteriophage MS2	ssRNA	150	0.01540	W	Wat	N	1	30	0.02	3.569	Shin 2005
Bacteriophage MS2	ssRNA	140	0.01640	W	Wat	N	1	-	0.02	3.569	Meng 1996
Bacteriophage MS2	ssRNA	198	0.01160	W	Wat	N	1	1520	0.02	3.569	Nieuwstad 1994

APPENDIX B: UV Rate Constants for Viruses

Microbe	Type	D_{90} J/m^2	UVGI k m^2/J	Media	RH %	Sh	St	UL J/m^2	Dia. µm	Base Pairs kb	Source (see Chapter 4 Refs)
Bacteriophage MS2	ssRNA	228	0.01010	W	Wat	N	1	1550	0.02	3.569	Lazarova 2004
Bacteriophage MS2	ssRNA	245	0.00940	W	Wat	N	1	-	0.02	3.569	Thompson 2003
Bacteriophage Qβ	ssRNA	125	0.01840	W	Wat	N	1	1500	-	-	Simonet 2006
Bacteriophage Qβ	ssRNA	1919	0.00120	W	Wat	N	1	2500	-	-	O'Hara 1980
Berne virus	ssRNA	13	0.18420	W	Wat	-	-	-	0.13	20	Weiss 1986
BF-NNV (fish virus)	ssRNA	501	0.00460	W	Wat	-	-	-	-	-	Yoshimizu 2005
BLV	ssRNA	1799	0.00128	W	Wat	Y	2	400	0.1	8.419	Shimizu 2004
BLV	ssRNA	221	0.01040	W	Wat	N	1	1000	0.1	8.419	Guillemain 1981
Borna virus	ssRNA	79	0.02920	W	Wat	-	-	-	0.09	8.91	Danner 1979
Bovine Calicivirus	ssDNA	95	0.02420	W	Wat	-	-	-	0.02	7.45	Malley 2004
Bovine Parvovirus	ssDNA	35	0.06580	W	-	-	-	-	0.02	5.517	vonBrodorotti 1982
Canine Calicivirus	ssRNA	67	0.03450	W	Wat	N	1	800	0.037	8.513	deRodaHusman 2004
Canine hepatic Adenovirus	dsDNA	265	0.00869	W	Wat	-	-	-	0.08	36.5	vonBrodorotti 1982
CCHV (fish virus)	dsDNA	5	0.46050	W	Wat	-	-	-	-	130	Yoshimizu 2005
Cholera phage Kappa	dsDNA	634	0.00363	W	Wat	N	1	1919	-	-	Samad 1987
Coliphage f2	ssRNA	310	0.00743	W	Wat	-	-	-	-	-	Severin 1983
Coliphage fd	ssDNA	23	0.09940	W	Wat	N	1	900	-	-	Rauth 1965
Coliphage ϕX-174	ssDNA	3	0.71000	Air	Lo RH	N	1	12	0.025	5.386	Tseng 2005
Coliphage ϕX-174	ssDNA	4	0.53000	Air	Hi RH	N	1	12	0.025	5.386	Tseng 2005
Coliphage ϕX-174	ssDNA	18	0.12800	W	Wat	N	1	42	0.025	5.386	Yarus 1964
Coliphage ϕX-174	ssDNA	21	0.11140	W	Wat	N	1	90	0.025	5.386	Setlow 1960
Coliphage ϕX-174	ssDNA	21	0.11090	W	Wat	N	1	900	0.025	5.386	Rauth 1965
Coliphage ϕX-174	ssDNA	30	0.07650	W	Wat	-	-	-	0.025	5.386	Proctor 1972
Coliphage ϕX-174	ssDNA	25	0.09200	W	Wat	N	2	2000	0.025	5.386	Gurzadyan 1981
Coliphage ϕX-174	ssDNA	14	0.16060	W	Wat	-	-	-	0.025	5.386	David 1964
Coliphage ϕX-174	ssDNA	25	0.09350	W	Wat	N	1	105	0.025	5.386	Sommer 1998
Coliphage ϕX-174	ssDNA	57	0.04013	W	Wat	N	1	130	0.025	5.386	Sommer 2001
Coliphage ϕX-174	ssDNA	177	0.01300	W	Wat	N	1	800	0.025	5.386	Nuanualsuwan 2002
Coliphage ϕX-174	ssDNA	23	0.10230	W	Wat	N	1	150	0.025	5.386	Battigelli 1993
Coliphage ϕX-174	ssDNA	40	0.05760	W	Wat	N	1	120	0.025	5.386	Oppenheimer 1993
Coliphage ϕX-174	ssDNA	18	0.12910	W	Wat	N	1	70	0.025	5.386	Giese 2000
Coliphage lambda	dsDNA	57	0.04050	W	Wat	N	2	600	0.05	168.9	Gurzadyan 1981
Coliphage lambda	dsDNA	70	0.03310	W	Wat	-	-	-	0.05	168.9	Harm 1961
Coliphage lambda	dsDNA	72	0.03200	W	Wat	Y	1	-	0.05	168.9	Weigle 1953
Coliphage lambda	dsDNA	184	0.01250	W	Wat	N	2	1100	0.05	168.9	Davidovich 1991
Coliphage PRD1	dsDNA	87	0.02650	S	-	N	1	-	0.062	14.925	Meng 1996
Coliphage PRD1	dsDNA	20	0.11500	W	Wat	N	1	10	0.062	14.925	Shin 2005
Coliphage T1	dsDNA	6	0.36970	W	Wat	-	-	-	0.05	48.836	Hotz 1969
Coliphage T1	dsDNA	38	0.06000	W	Wat	N	1	200	0.05	48.836	Harm 1968
Coliphage T1	dsDNA	40	0.05800	W	Wat	N	1	60	0.05	48.836	Fluke 1949 (265 nm)
Coliphage T2	dsDNA	5	0.48400	W	Wat	N	1	900	0.065	-	Rauth 1965
Coliphage T2	dsDNA	9	0.25600	W	Wat	-	-	-	0.065	-	Jagger 1956
Coliphage T2	dsDNA	133	0.01730	W	Wat	Y	1	927	0.065	-	Dulbecco 1952
Coliphage T3	dsDNA	10	0.23100	W	Wat	Y	1	-	0.045	-	Winkler 1962
Coliphage T4	dsDNA	7	0.34500	W	Wat	N	1	60	0.089	168.9	Otaki 2003
Coliphage T4	dsDNA	14	0.16850	W	Wat	N	1	19	0.089	168.9	Ross 1971
Coliphage T4	dsDNA	15	0.15400	W	Wat	N	1	40	0.089	168.9	Harm 1968
Coliphage T4	dsDNA	29	0.08000	W	Wat	N	1	50	0.089	168.9	Templeton 2006
Coliphage T4	dsDNA	22	0.10700	W	Wat	Y	1	-	0.089	168.9	Winkler 1962
Coliphage T4	dsDNA	12	0.20000	W	Wat	N	2	40	0.089	168.9	Bohrerova 2008
Coliphage T7	dsDNA	7	0.33000	Air	Lo RH	N	1	12	0.063	39.937	Tseng 2005
Coliphage T7	dsDNA	10	0.22000	Air	Hi RH	N	1	12	0.063	39.937	Tseng 2005
Coliphage T7	dsDNA	95	0.02420	W	Wat	N	1	-	0.063	39.937	Benzer 1952
Coliphage T7	dsDNA	53	0.04320	W	Wat	N	1	180	0.063	39.937	Peak 1978 (B)
Coliphage T7	dsDNA	41	0.05600	W	Wat	Y	1	200	0.063	39.937	Bohrerova 2008 (LP)
Coliphage T7	dsDNA	38	0.06100	W	Wat	Y	1	200	0.063	39.937	Bohrerova 2008 (MP)
Coliphage T7	dsDNA	23	0.10000	W	Wat	N	1	-	0.063	39.937	Ronto 1992
Coliphage T7	dsDNA	11	0.20470	W	Wat	N	1	45	0.063	39.937	Peak 1978 (Bs-1)
Coronavirus	ssRNA	3	0.37700	Air	50	N	1	6	0.113	30.738	Walker 2007
Coronavirus	ssRNA	7	0.32100	W	Wat	-	-	-	0.113	30.738	Weiss 1986
Coronavirus (SARS)	ssRNA	226	0.01000	W	Wat	N	2	1200	0.113	29.751	Kariwa 2004
Coronavirus (SARS)	ssRNA	3046	0.00076	W	Wat	N	2	14458	0.113	29.751	Darnell 2004
Coxsackievirus	ssRNA	21	0.11100	Air	60	N	1	68	0.027	7.413	Jensen 1964

APPENDIX B: UV Rate Constants for Viruses

Microbe	Type	D_{90} J/m^2	UVGI k m^2/J	Media	RH %	Sh	St	UL J/m^2	Dia. µm	Base Pairs kb	Source (see Chapter 4 Refs)
Coxsackievirus	ssRNA	128	0.02000	W	Wat	N	1	348	0.027	7.413	Hill 1970
Coxsackievirus	ssRNA	86	0.02684	W	Wat	N	1	300	0.027	7.413	Havelaar 1987
Coxsackievirus B3	ssRNA	80	0.02878	W	Wat	N	1	400	0.027	7.413	Gerba 2002
Coxsackievirus B4	ssRNA	60	0.03840	W	Wat	N	1	30	0.027	7.413	Shin 2005
Coxsackievirus B5	ssRNA	95	0.02424	W	Wat	N	1	400	0.027	7.413	Gerba 2002
Coxsackievirus B5	ssRNA	72	0.03180	W	Wat	N	1	200	0.027	7.413	Battigelli 1993
CSV (fish virus)	dsRNA	501	0.00460	W	Wat	-	-	1000	-	-	Yoshimizu 2005
Echovirus (Parechovirus)	ssRNA	106	0.02190	W	Wat	N	1	348	0.024	7.354	Hill 1970
Echovirus 1	ssRNA	80	0.02878	W	Wat	N	1	400	0.024	7.354	Gerba 2002
Echovirus 2	ssRNA	70	0.03289	W	Wat	N	1	400	0.024	7.354	Gerba 2002
Encephalomyocarditis virus	ssRNA	50	0.04650	W	Wat	N	1	21	0.025	7.835	Ross 1971
Encephalomyocarditis virus	ssRNA	52	0.04460	W	Wat	N	1	900	0.025	7.835	Rauth 1965
Encephalomyocarditis virus	ssRNA	65	0.03550	W	Wat	Y	1	8	0.025	7.835	Zavadova 1968
Epstein-Barr virus (EBV)	ssDNA	162	0.01420	W	Wat	N	1	15000	-	-	Henderson 1978
Equine Herpes virus	dsDNA	25	0.09210	W	Wat	-	-	-	0.105	145.597	Weiss 1986
EVA (fish virus)	ssRNA	5	0.46050	W	Wat	-	-	-	0.06	12.7	Yoshimizu 2005
EVEX (fish virus)	ssRNA	5	0.46050	W	Wat	-	-	-	0.06	11	Yoshimizu 2005
Feline Calicivirus (FeCV)	ssRNA	434	0.00530	W	Wat	N	2	1300	0.034	7.683	Nuanualsuwan 2002
Feline Calicivirus (FeCV)	ssRNA	80	0.02880	W	Wat	N	1	200	0.034	7.683	Thurston-Enriquez 2003
Feline Calicivirus (FeCV)	ssRNA	40	0.05760	W	Wat	N	1	800	0.034	7.683	deRodaHusman 2004
Feline Calicivirus (FeCV)	ssRNA	44	0.05270	W	Wat	N	1	140	0.034	7.683	Tree 2005
Friend Murine Leukemia v.	ssRNA	320	0.00720	W	Wat	N	1	1200	0.094	8.323	Yoshikura 1971
Frog virus 3	dsDNA	25	0.09210	W	Wat	N	1	25	0.167	105.903	Martin 1982
Hepatitis A virus	dsDNA	40	0.05760	W	Wat	N	1	150	0.027	7.478	Battigelli 1993
Hepatitis A virus	dsDNA	45	0.05120	W	Wat	N	1	180	0.027	7.478	Wang 2004
Hepatitis A virus	dsDNA	50	0.04610	W	Wat	-	-		0.027	7.478	Weidenmann 1993
Hepatitis A virus	dsDNA	92	0.02500	W	Wat	N	1	368	0.027	7.478	Wang 1995
Hepatitis A virus	dsDNA	98	0.02340	W	Wat	-	-	-	0.027	7.478	Wilson 1992
Hepatitis A virus	dsDNA	307	0.00750	W	Wat	N	2	1300	0.027	7.478	Nuanualsuwan 2002
Herpes simplex virus (HRE)	dsDNA	40	0.05760	W	Wat	N	1	80	0.18	152.261	Powell 1959
Herpes simplex virus Type 1	dsDNA	71	0.03260	W	Wat	N	2	450	0.184	152.261	Bockstahler 1976
Herpes simplex virus Type 1	dsDNA	110	0.02090	W	Wat	N	2	200	0.184	152.261	Selsky 1978
Herpes simplex virus Type 1	dsDNA	25	0.09330	W	Wat	N	2	300	0.184	152.261	Lytle 1971
Herpes Simplex virus Type 1	dsDNA	35	0.06540	W	Wat	N	2	19	0.184	152.261	Ross 1971
Herpes Simplex virus Type 1	dsDNA	21	0.11050	W	Wat	N	2	40	0.184	152.261	Albrecht 1974
Herpes Simplex virus Type 1	dsDNA	41	0.05680	W	Wat	N	1	20	0.184	152.261	Henderson 1978
Herpes Simplex virus Type 2	dsDNA	40	0.05756	W	Wat	-	-	-	0.173	154.746	Wolff 1973
Herpes Simplex virus Type 2	dsDNA	41	0.05650	W	Wat	N	2	19	0.173	154.746	Ross 1971
Herpes Simplex virus Type 2	dsDNA	75	0.03070	W	Wat	N	2	80	0.173	154.746	Ryan 1986
Herpes Simplex virus Type 2	dsDNA	20	0.11800	W	Wat	N	2	40	0.173	154.746	Albrecht 1974
HIV-1	ssRNA	280	0.00822	W	Wat	Y	1	400	0.125	9.181	Yoshikura 1989
HIRRV (fish virus)	ssRNA	5	0.46050	W	Wat	-	-	-	0.06	11	Yoshimizu 2005
HP1c1 phage	dsDNA	40	0.05760	W	Wat	N	2	180	0.062	32.35	Setlow 1972
HTLV-1	ssRNA	20	0.11510	W	Wat	N	1	35	0.102	8.507	Shimizu 2004
Human Cytomegalovirus	dsDNA	658	0.00350	S	-	Y	1	1950	0.1	-	Hirai 1977
Human Cytomegalovirus	dsDNA	50	0.04605	S	-	N	2	-	0.1	-	Albrecht 1974
Influenza A virus	ssRNA	19	0.11900	Air	68	N	1	68	0.098	13.498	Jensen 1964
Influenza A virus	ssRNA	20	0.11700	W	Wat	N	1	9	0.098	13.498	Ross 1971
Influenza A virus	ssRNA	48	0.04800	W	Wat	Y	1	-	0.098	13.498	Hollaender 1944
Influenza A virus	ssRNA	17	0.13810	W	Wat	N	1	14	0.098	13.498	Abraham 1979
IHNV (fish virus)	ssRNA	5	0.46050	W	Wat	-	-	-	0.09	12	Yoshimizu 2005
IHNV (fish virus)	ssRNA	7	0.34500	W	Wat	-	-	-	0.09	12	Sako 1985
IPNV (fish virus)	dsRNA	397	0.00580	W	Wat	N	2	2000	0.06	6	Oye 2001
IPNV (fish virus)	dsRNA	407	0.00566	W	Wat	N	2	1220	0.06	6	Liltved 1995
IPNV (fish virus)	dsRNA	501	0.00460	W	Wat	-	-	-	0.06	6	Yoshimizu 2005
IPNV (fish virus)	dsRNA	626	0.00368	W	Wat	-	-	1500	0.06	6	Ahne 1982
IPNV (fish virus)	dsRNA	583	0.00395	W	Wat	-	-	2000	0.06	6	Sako 1985
Iridovirus (Bohle) (fish virus)	dsDNA	83	0.02760	W	Wat	-	-	-	-	-	Miocevic 1993
ISAV (fish virus)	ssRNA	11	0.20900	W	Wat	N	2	70	-	12.7	Oye 2001
ISAV (fish virus)	ssRNA	26	0.08970	W	Wat	-	-	-	-	12.7	Liltved 1995
JF-LCDV (fish virus)	dsDNA	5	0.46050	W	Wat	-	-	-	0.14	102.6	Yoshimizu 2005
Kemerovo (R-10 strain)	dsRNA	230	0.01000	W	Wat	N	1	900	0.075	-	Zavadova 1975
Kilham Rat Virus (parvovirus)	ssDNA	30	0.07650	W	Wat	-	-	-	0.022	5	Proctor 1972

APPENDIX B: UV Rate Constants for Viruses

Microbe	Type	D_{90} J/m^2	UVGI k m^2/J	Media	RH %	Sh	St	UL J/m^2	Dia. µm	Base Pairs kb	Source (see Chapter 4 Refs)
Lipovnik (Lip-91 strain)	dsRNA	299	0.00770	W	Wat	N	2	200	0.075	-	Zavadova 1975
LLE46 (SV/Adeno hybrid)	dsDNA	606	0.00380	W	Wat	N	1	2376	-	-	Defendi 1967
Measles virus	ssRNA	22	0.10510	W	Wat	N	1	48	0.329	15.894	DiStefano 1976
Mengovirus	dsRNA	162	0.01420	W	Wat	N	2	70	-	6.1	Miller 1974
Minute Virus of Mice (MVM)	ssDNA	28	0.08200	W	Wat	N	1	8	0.022	5.081	Vos 1981
Minute Virus of Mice (MVM)	ssDNA	17	0.13500	W	Wat	N	1	70	0.022	5.081	Rommelaere 1981
Murine Cytomegalovirus	dsDNA	46	0.05000	W	Wat	N	2	116	0.104	230.278	Shanley 1982
Moloney Murine Leukemia v.	ssRNA	115	0.02000	W	Wat	N	1	330	0.094	8.332	Nomura 1972
Moloney Murine Leukemia v.	ssRNA	370	0.00622	W	Wat	N	1	1000	0.094	8.332	Guillemain 1981
Moloney Murine Leukemia v.	ssRNA	280	0.00822	W	Wat	-			0.094	8.332	Yoshikura 1989
Murine Norovirus (MNV)	ssRNA	76	0.03040	W	Wat	N	1	250	0.032	7.382	Lee 2008
Murine sarcoma virus	ssRNA	237	0.00970	W	Wat	N	1	432	0.12	5.833	Nomura 1972
Murine sarcoma virus	ssRNA	144	0.01600	W	Wat	N	1	74	0.12	5.833	Kelloff 1970
Murine sarcoma virus	ssRNA	299	0.00770	W	Wat	N	1	300	0.12	5.833	Yoshikura 1971
Mycobacteriophage D29	dsDNA	16	0.14300	W	Wat	N	2	120	0.065	49.136	David 1973
Mycobacteriophage D29	dsDNA	324	0.00710	W	Wat	N	2	950	0.065	49.136	Sellers 1970
Mycobacteriophage D29A	dsDNA	268	0.00860	W	Wat	N	2	950	0.065	49.136	Sellers 1970
Mycobacteriophage D32	dsDNA	354	0.00650	W	Wat	N	1	950	-	-	Sellers 1970
Mycobacteriophage D4	dsDNA	245	0.00940	W	Wat	N	1	950	-	-	Sellers 1970
Mycoplasmavirus MVL2	dsDNA	154	0.01500	W	Wat	Y	1	600	-	-	Das 1977
Mycoplasmavirus MVL51	ssDNA	79	0.02900	W	Wat	Y	1	250	-	-	Das 1977
Newcastle Disease Virus	ssRNA	8	0.27600	W	Wat	-	-	-	0.212	15.186	vonBrodorotti 1982
Newcastle Disease Virus	ssRNA	45	0.05110	W	Wat	N	1	90	0.212	15.186	Levinson 1966
Newcastle Disease Virus	ssRNA	16	0.14400	S	-	N	1	50	0.212	15.186	Rubin 1959
OMV (fish virus)	ssRNA	5	0.46050	W	Wat	-	-	-	0.06	-	Yoshimizu 2005
Parvovirus H-1	ssDNA	25	0.09200	W	Wat	N	1	55	0.022	6.194	Cornellis 1982
PFRV (fish virus)	ssRNA	5	0.46050	W	Wat	-	-	-	0.06	11	Yoshimizu 2005
phage GA	ssRNA	200	0.01150	W	Wat	N	1	1500	-	-	Simonet 2006
phage phi 6	dsRNA	5	0.43000	Air	Lo RH	N	1	12	-	-	Tseng 2005
phage phi 6	dsRNA	7	0.31000	Air	Hi RH	N	1	12	-	-	Tseng 2005
phage B40-8 (B. fragilis)	dsDNA	67	0.03450	W	Wat	Y	1	400	-	-	Sommer 2001
phage B40-8 (B. fragilis)	dsDNA	86	0.02690	W	Wat	N	1	280	-	-	Sommer 1998
Poliovirus	dsRNA	44	0.05230	S	-	N	1	220	0.0248	7.44	Ma 1994
Poliovirus type 1	dsRNA	41	0.05620	S	-	N	1	-	0.0248	7.44	Meng 1996
Poliovirus	dsRNA	71	0.03250	W	Wat	Y	1	216	0.0248	7.44	Helentjaris 1977
Poliovirus	dsRNA	75	0.03070	W	Wat	N	1	30	0.0248	7.44	Shin 2005
Poliovirus	dsRNA	95	0.02420	W	Wat	N	1	54	0.0248	7.44	Bishop 1967
Poliovirus	dsRNA	52	0.04460	W	Wat	N	1	900	0.0248	7.44	Dulbecco 1955
Poliovirus type 1	dsRNA	67	0.03450	W	Wat	N	2	300	0.0248	7.44	Chang 1985
Poliovirus type 1	dsRNA	72	0.03200	W	Wat	-	-	-	0.0248	7.44	Wilson 1992
Poliovirus type 1	dsRNA	96	0.02400	W	Wat	N	1	480	0.0248	7.44	Wetz 1982
Poliovirus type 1	dsRNA	100	0.02300	W	Wat	-	-	-	0.0248	7.44	Thompson 2003
Poliovirus type 1	dsRNA	125	0.01840	W	Wat	-	-	-	0.0248	7.44	Oppenheimer 1997
Poliovirus type 1	dsRNA	224	0.01030	W	Wat	N	1	1165	0.0248	7.44	Nuanualsuwan 2003
Poliovirus type 1	dsRNA	240	0.00960	W	Wat	N	1	1300	0.0248	7.44	Nuanualsuwan 2002
Poliovirus type 1	dsRNA	111	0.02080	W	Wat	N	1	348	0.0248	7.44	Hill 1970
Poliovirus type 1	dsRNA	77	0.03000	W	Wat	N	1	-	0.0248	7.44	Harris 1987
Poliovirus type 1	dsRNA	80	0.02878	W	Wat	N	1	400	0.0248	7.44	Gerba 2002
Poliovirus type 1	dsRNA	83	0.02760	W	Wat	N	1	1500	0.0248	7.44	Simonet 2006
Poliovirus type 1	dsRNA	57	0.04010	W	Wat	N	1	270	0.0248	7.44	Tree 2005
Poliovirus type 2	dsRNA	121	0.01910	W	Wat	N	1	348	0.0248	7.44	Hill 1970
Poliovirus type 3	dsRNA	103	0.02240	W	Wat	N	1	348	0.0248	7.44	Hill 1970
Polyomavirus	dsDNA	480	0.00480	W	Wat	N	1	240	0.0424	5	vander Eb 1967
Polyomavirus	dsDNA	640	0.00360	W	Wat	N	1	2376	0.0424	5	Defendi 1967
Polyomavirus	dsDNA	696	0.00331	W	Wat	N	1	900	0.0424	5	Rauth 1965
Polyomavirus	dsDNA	501	0.00460	W	Wat	-	-	-	0.0424	5	Latarjet 1967
Polyomavirus (ssDNA)	ssDNA	120	0.01920	W	Wat	N	2	240	0.045	5	vander Eb 1967
Porcine Parvovirus (PPV)	ssDNA	23	0.10230	W	Wat	N	1	90	0.021	6.194	Wang 2004
Pseudorabies (PRV)	dsDNA	34	0.06760	W	Wat	N	2	15	0.194	-	Ross 1971
Rabies virus (env)	ssRNA	10	0.21930	W	Wat	-	-	-	0.07	11.932	Weiss 1986
Rauscher Murine Leukemia v.	ssRNA	157	0.01470	W	Wat	N	1	74	0.094	8.282	Kelloff 1970
Rauscher Murine Leukemia v.	ssRNA	480	0.00480	W	Wat	N	1	200	0.094	8.282	Lovinger 1975
Rauscher Murine Leukemia v.	ssRNA	959	0.00240	S	-	N	2	4800	0.094	8.282	Stull 1976

APPENDIX B: UV Rate Constants for Viruses

Microbe	Type	D_{90} J/m^2	UVGI k m^2/J	Media	RH %	Sh	St	UL J/m^2	Dia. µm	Base Pairs kb	Source (see Chapter 4 Refs)
Reovirus	dsRNA	175	0.01316	W	Wat	N	1	348	0.075	11	Hill 1970
Reovirus	dsRNA	186	0.01240	W	Wat	N	1	740	0.075	11	Wang 2004
Reovirus	dsRNA	69	0.03358	W	Wat	-	-	-	0.075	11	vonBrodorotti 1982
Reovirus	dsRNA	245	0.00940	W	Wat	N	2	990	0.075	11	Shaw 1973
Reovirus	dsRNA	121	0.01910	W	Wat	N	1	900	0.075	11	Rauth 1965
Reovirus	dsRNA	270	0.00853	W	Wat	N	2	1080	0.075	11	McClain 1966
Reovirus	dsRNA	174	0.01320	W	Wat	N	1	348	0.075	11	Hill 1970
Reovirus type 1	dsRNA	153	0.01508	W	Wat	N	1	-	0.075	11	Harris 1987
Reovirus 3	dsRNA	334	0.00690	W	Wat	N	2	300	0.075	11	Zavadova 1975
Rotavirus	dsRNA	200	0.01150	W	Wat	N	2	200	0.07	-	Caballero 2004
Rotavirus SA11	dsRNA	89	0.02600	W	Wat	-	-	-	0.07	-	Wilson 1992
Rotavirus SA11	dsRNA	75	0.03070	W	Wat	N	1	750	0.07	-	Meng 1987
Rotavirus SA11	dsRNA	105	0.02190	W	Wat	N	2	250	0.07	-	Battigelli 1993
Rotavirus SA11	dsRNA	100	0.02300	W	Wat	N	1	350	0.07	-	Chang 1985
Rotavirus SA11	dsRNA	84	0.02740	W	Wat	N	1	380	0.07	-	Sommer 1989
Rous Sarcoma virus (RSV)	ssRNA	720	0.00320	W	Wat	N	1	36	0.127	9.392	Levinson 1966
Rous Sarcoma virus (RSV)	ssRNA	240	0.00960	W	Wat	-	-	-	0.127	9.392	Golde 1961
Rous Sarcoma virus (RSV)	ssRNA	200	0.01150	S	-	N	1	700	0.127	9.392	Rubin 1959
SBNN (fish virus)	ssRNA	698	0.00330	W	Wat	Y	2	2640	-	-	Frerichs 2000
Semliki forest virus	ssRNA	25	0.09210	W	Wat	-	-	-	0.061	11.442	Weiss 1986
Simian virus 40	dsDNA	2503	0.00092	W	Wat	N	1	2500	0.045	5.243	Bourre 1989
Simian virus 40	dsDNA	1599	0.00144	W	Wat	N	2	8000	0.045	5.243	Seemayer 1973
Simian virus 40	dsDNA	1439	0.00160	W	Wat	N	1	1500	0.045	5.243	Cornellis 1981
Simian virus 40	dsDNA	1245	0.00185	W	Wat	-	-	-	0.045	5.243	Bockstahler 1977
Simian virus 40	dsDNA	886	0.00260	W	Wat	N	1	2376	0.045	5.243	Defendi 1967
Simian virus 40	dsDNA	650	0.00354	W	Wat	N	1	1300	0.045	5.243	Sarasin 1978
Simian virus 40	dsDNA	443	0.00520	W	Wat	-	-	240	0.045	5.243	Aaronson 1970
Simian virus 40	dsDNA	23	0.10040	W	Wat	N	1	55	0.045	5.243	Cornellis 1982
Simian virus 40	dsDNA	17	0.13160	W	Wat	N	1	70	0.045	5.243	Wang 2004
Sindbis virus	ssRNA	22	0.10400	Air	62	N	1	68	0.075	11.703	Jensen 1964
Sindbis virus	ssRNA	60	0.03864	W	Wat	-	-	-	0.075	11.703	vonBrodorotti 1982
Sindbis virus	ssRNA	113	0.02030	W	Wat	N	1	400	0.075	11.703	Wang 2004
Sindbis virus	ssRNA	50	0.04610	W	Wat	N	1	200	0.075	11.703	Zavadova 1975
S. aureus phage	dsDNA	82	0.02800	S	-	N	1	30	-	-	Gates 1934
S. aureus phage	dsDNA	77	0.03000	S	-	N	1	4	-	-	Sturm 1932
S. aureus phage A994	dsDNA	65	0.03542	W	Wat	-	-	-	-	-	Sommer 1989
SVCV (fish virus)	ssRNA	10	0.46050	W	Wat	-	-	-	0.06	11.1	Yoshimizu 2005
Vaccinia virus	dsDNA	1	2.54000	Air	60	N	1	3	0.307	195.815	McDevitt 2007
Vaccinia virus	dsDNA	15	0.15300	Air	65	N	1	68	0.307	195.815	Jensen 1964
Vaccinia virus	dsDNA	7	0.34900	W	Wat	N	1	10	0.307	195.815	Galasso 1965
Vaccinia virus	dsDNA	14	0.16450	W	Wat	N	1	30	0.307	195.815	Bossart 1978
Vaccinia virus	dsDNA	14	0.16040	W	Wat	N	1	6	0.307	195.815	Ross 1971
Vaccinia virus	dsDNA	18	0.12792	W	Wat	N	1	20	0.307	195.815	Klein 1994
Vaccinia virus	dsDNA	22	0.10500	W	Wat	N	2	8	0.307	195.815	Zavadova 1971
Vaccinia virus	dsDNA	28	0.08290	W	Wat	N	1	900	0.307	195.815	Rauth 1965
Vaccinia virus	dsDNA	715	0.00322	W	Wat	N	2	70000	0.307	195.815	Davidovich 1991
Vaccinia virus	dsDNA	677	0.00340	W	Wat	N	1	4300	0.307	195.815	Collier 1955
VEE	ssRNA	55	0.04190	W	Wat	-	-	-	0.065	11.444	Smirnov 1992
Vesicular Stomatitis virus	ssRNA	13	0.18060	W	Wat	N	1	900	0.104	11.161	Rauth 1965
Vesicular Stomatitis virus	ssRNA	12	0.19000	W	Wat	-	-	-	0.104	11.161	Helentjaris 1977
Vesicular Stomatitis virus	ssRNA	100	0.02300	W	Wat	N	1	10	0.104	11.161	Bay 1979
Vesicular Stomatitis virus	ssRNA	6	0.38400	W	Wat	N	1	-	0.104	11.161	Shimizu 2004
VHSV (fish virus)	ssRNA	3	0.87400	W	Wat	-	-	20	0.07	11.158	Oye 2001
WEE	ssRNA	54	0.04300	W	Wat	N	1	83	0.07	11.484	Dubinin 1975

NOTES for Appendices A, B & C:

Type: Sp = Spore, Veg = Vegetative, VegY = Vegetative yeast

D_{90}: UV Dose for 90% inactivation (10% survival)

UVGI k: UV rate constant at the given D_{90} (and below the UL)

UL: Upper Limit within which D_{90} and rate constants are applicable

Media: A = Air, S = Surface, W = Water RH = Relative Humidity

Sh = Shoulder in decay curve (shoulder is ignored for k and D_{90} values)

St = Number of stages in decay curve (k & D_{90} only applies to first stage)

Dia.: Logmean diameter in microns, including envelope for viruses if any

MP: Medium Pressure UV lamp, LP: Low Pressure UV lamp

APPENDIX C: UV Rate Constants for Fungi and Other Microbes

Microbe	Type	D_{90} J/m^2	UVGI k m^2/J	Media	RH %	Sh	St	UL J/m^2	Dia. µm	Base Pairs kb	Source (see Chapter 4 Refs)
Aspergillus amstelodami	Sp	700	0.00329	W	Wat	-	-	-	3.354	35900	Jepson 1973
Aspergillus amstelodami	Sp	258	0.00892	S	-	N	1	336	3.354	35900	Luckiesh 1949
Aspergillus amstelodami	Sp	669	0.00344	Air	67	N	2	870	3.354	35900	Luckiesh 1949
Aspergillus flavus	Sp	349	0.00660	S	-	N	1	35	4.24	35900	Green 2004
Aspergillus flavus	Sp	600	0.00384	-	-	-	-	-	4.24	35900	Nagy 1964
Aspergillus flavus	Sp	853	0.00270	W	Wat	N	1	13932	4.24	35900	Begum 2009
Aspergillus fumigatus	Sp	535	0.00430	S	-	N	1	54	4.24	35900	Green 2004
Aspergillus fumigatus	Veg	560	0.00411	S	-	-	-	560	24.5	35900	Chick 1963
Aspergillus fumigatus	Sp	2240	0.00103	S	-	-	-	2240	2.64	35900	Chick 1963
Aspergillus glaucus	Sp	440	0.00523	-	-	-	-	-	3.354	35900	Nagy 1964
Aspergillus niger	Sp	1771	0.00130	S	Lo RH	Y	2	1600	3.354	35900	Zahl 1939
Aspergillus niger	Sp	1439	0.00160	S	-	-	2	3384	3.354	35900	Fulton 1929
Aspergillus niger	Veg	4480	0.00051	S	-	-	-	4480	3.354	35900	Chick 1963
Aspergillus niger	Sp	1000	0.00230	W	Wat	-	-	-	3.354	35900	Jepson 1973
Aspergillus niger	Sp	315	0.00350	S	-	Y	2	18	3.354	35900	Kowalski 2001
Aspergillus niger	Sp	1387	0.00166	S	-	N	1	1800	3.354	35900	Luckiesh 1949
Aspergillus niger	Sp	750	0.00386	S	-	-	-	3000	3.354	35900	Gritz 1990
Aspergillus niger	Sp	4480	0.00051	S	-	-	-	4480	3.354	35900	Chick 1963
Aspergillus niger	Sp	3984	0.00058	Air	55	N	2	5400	3.354	35900	Luckiesh 1949
Aspergillus niger	Sp	1320	0.00174	-	-	-	-	-	3.354	35900	Nagy 1964
Aspergillus niger	Sp	1681	0.00137	W	Wat	N	2	9288	3.354	35900	Begum 2009
Aspergillus versicolor	Sp	384	0.00600	Air	85	N	1	32	3.354	35900	vanOsdell 2002
Aspergillus versicolor	Sp	768	0.00300	Air	55	N	1	32	3.354	35900	vanOsdell 2002
Aspergillus versicolor	Sp	139	0.01660	Air	50	N	1	32	3.354	35900	vanOsdell 2002
Aspergillus versicolor	Veg	96	0.02400	Air	(Lo RH)	N	1	940	3.354	35900	Nakamura 1987
Blastomyces dermatitidis	VegY	140	0.01645	S	-	-	-	140	11.000	23000	Chick 1963
Botrytis cinerea	Sp	250	0.00920	S	-	N	1	1000	11.180	42660	Marquenie 2002
Candida albicans	VegY	230	0.01100	W	Wat	N	2	440	4.899	20000	Dolman 1989
Candida albicans	VegY	447	0.00515	W	Wat	N	1	453	4.899	20000	Abshire 1981
Candida albicans	VegY	750	0.00407	S	-	-	-	3000	4.899	20000	Gritz 1990
Candida albicans	VegY	280	0.00822	S	-	-	-	280	4.899	20000	Chick 1963
Candida parapsilosis	VegY	98	0.02360	W	Wat	N	1	390	-	-	Severin 1983
Cladosporium herbarum	Sp	500	0.04605	W	Wat	-	-	-	8.062	36000	Jepson 1973
Cladosporium herbarum	Sp	189	0.01220	S	-	N	1	246	8.062	36000	Luckiesh 1949
Cladosporium herbarum	Sp	622	0.00370	Air	53	N	2	810	8.062	36000	Luckiesh 1949
Cladosporium trichoides	Veg	560	0.00411	S	-	-	-	560	8.062	36000	Chick 1963
Cladosporium trichoides	Sp	1120	0.00206	S	-	-	-	1120	8.062	36000	Chick 1963
C. sphaerospermum	Sp	1439	0.00210	Air	50	N	1	32	8.062	36000	vanOsdell 2002
Cladosporium wernecki	Sp	4480	0.00051	S	-	-	-	4480	8.062	36000	Chick 1963
Cladosporium wernecki	Veg	560	0.00411	S	-	-	-	560	8.062	36000	Chick 1963
Cryptococcus neoformans	Sp	138	0.01670	S	-	N	1	400	4.899	23000	Wang 1994
Cryptococcus neoformans	VegY	280	0.00822	S	-	-	-	280	4.899	23000	Chick 1963
Curvularia lunata	Veg	560	0.00411	S	-	-	-	560	17.100	29700	Chick 1963
Eurotium rubrum	Sp	434	0.00531	W	Wat	N	2	4644	5.612	-	Begum 2009
Fusarium oxysporum	Sp	260	0.01420	W	Wat	Y	2	600	11.225	43000	Asthana 1992
Fusarium solani	Sp	313	0.00735	W	Wat	N	2	960	11.225	43000	Asthana 1992
Fusarium spp.	Sp	560	0.00411	S	-	-	-	560	11.225	43000	Chick 1963
Fusarium spp.	Veg	1120	0.00206	S	-	-	-	1120	34.300	43000	Chick 1963
Histoplasma capsulatum	Veg	140	0.01645	S	-	-	-	140	2.550	23000	Chick 1963
Monilinia fructigena	Sp	167	0.01380	S	-	N	1	500	10.300	-	Marquenie 2002
Mucor mucedo	Sp	600	0.00384	W	Wat	-	-	-	7.071	39000	Jepson 1973
Mucor mucedo	Sp	180	0.01280	S	-	N	1	234	7.071	39000	Luckiesh 1949
Mucor mucedo	Sp	577	0.00399	Air	63	N	2	750	7.071	39000	Luckiesh 1949
Mucor racemosus	Sp	170	0.01354	-	-	-	-	-	7.071	39000	Nagy 1964
Mucor spp.	Sp	140	0.01645	S	-	-	-	140	7.071	39000	Chick 1963
Mucor spp.	Veg	280	0.00822	S	-	-	-	280	31.600	39000	Chick 1963
Oospora lactis	Sp	28	0.08370	-	-	-	1	110	-	-	Nagy 1964
Penicillium chrysogenum	Sp	400	0.00576	W	Wat	-	-	-	3.262	34000	Jepson 1973
Penicillium chrysogenum	Sp	148	0.01560	S	-	N	1	192	3.262	34000	Luckiesh 1949
Penicillium chrysogenum	Sp	1645	0.00180	Air	50	N	1	32	3.262	34000	vanOsdell 2002
Penicillium chrysogenum	Sp	531	0.00434	Air	41	N	2	690	3.262	34000	Luckiesh 1949
Penicillium corylophilium	Sp	381	0.00604	W	Wat	N	2	4644	3.262	34000	Begum 2009
Penicillium digitatum	Sp	321	0.00718	W	Wat	Y	1	960	3.262	34000	Asthana 1992

APPENDIX C: UV Rate Constants for Fungi and Other Microbes

Microbe	Type	D_{90} J/m^2	UVGI k m^2/J	Media	RH %	Sh	St	UL J/m^2	Dia. µm	Base Pairs kb	Source (see Chapter 4 Refs)
Penicillium digitatum	Sp	440	0.00523	-	-	-	-	-	3.262	34000	Nagy 1964
Penicillium expansum	Sp	130	0.01771	-	-	-	-	-	3.262	34000	Nagy 1964
Penicillium italicum	Sp	321	0.01140	W	Wat	Y	2	590	3.262	34000	Asthana 1992
Penicillium roquefortii	Sp	130	0.01771	-	-	-	-	-	3.262	34000	Nagy 1964
Penicillium spp.	Sp	2240	0.00103	S	-	-	-	2240	3.262	34000	Chick 1963
Penicillium spp.	Veg	280	0.00822	S	-	-	-	280	8.800	34000	Chick 1963
Rhizopus nigricans	Sp	3000	0.00077	W	Wat	-	-	-	6.928	54178	Jepson 1973
Rhizopus nigricans	Sp	267	0.00861	Air	62	N	2	348	6.928	54178	Luckiesh 1949
Rhizopus nigricans	Sp	1110	0.00207	-	-	-	-	-	6.928	54178	Nagy 1964
Rhizopus nigricans	Sp	173	0.01330	S	-	Y	2	200	6.928	54178	Kowalski 2001
Rhizopus oryzae	Sp	4480	0.00051	S	-	-	-	4480	6.928	-	Chick 1963
Rhodotorula spp.	VegY	1120	0.00206	S	-	-	-	1120	5.900	-	Chick 1963
Saccharomyces spp.	VegY	44	0.05230	-	-	-	1	176	-	-	Nagy 1964
Saccharomyces ellipsoideus	VegY	33	0.06980	-	-	-	1	132	-	-	Nagy 1964
Scopulariopsis brevicaulis	Sp	650	0.01840	W	Wat	-	-	-	5.916	-	Jepson 1973
Scopulariopsis brevicaulis	Sp	226	0.01020	S	-	N	1	294	5.916	-	Luckiesh 1949
Scopulariopsis brevicaulis	Sp	2890	0.00344	Air	79	N	2	870	5.916	-	Luckiesh 1949
Sporotrichum schenkii	VegY	280	0.00822	S	-	-	-	280	5.500	-	Chick 1963
Stachybotrys chartarum	Sp	5575	0.00041	S	-	N	1	1440	5.623	-	Green 2005
Torula bergeri	Veg	4480	0.00051	S	-	-	-	4480	40	-	Chick 1963
Torula sphaerica	VegY	23	0.09986	Air	65	N	2	30	40	-	Luckiesh 1949
Torula sphaerica	VegY	78	0.02940	S	-	N	1	102	40	-	Luckiesh 1949
Trichophyton rubrum	Veg	560	0.00411	S	-	-	-	560	4.899	-	Chick 1963
Trichophyton rubrum	Sp	560	0.00411	S	-	-	-	560	4.899	-	Chick 1963
Ustilago zeae	VegY	1120	0.00206	S	-	-	-	1120	5.916	20500	Chick 1963
Ustilago zeae	Sp	35	0.06580	-	-	-	-	-	5.916	20500	Sussman 1966
Yeast	VegY	40	0.05756	W	Wat	-	-	-	-	-	Jepson 1973
Yeast (Brewer's)	VegY	100	0.02303	W	Wat	-	-	-	-	-	Jepson 1973
Protozoa and Other Microbes											
Acanthameoba	Rhizopod	999	0.02100	W	Wat	-	-	-	-	-	Maya 2003
Acanthameoba castellani	Rhizopod	992	0.00232	S	-	-	-	3000	-	-	Gritz 1990
Algae	Algae	1000	0.00230	-	-	-	-	-	-	-	Summer 1962
Algae, blue-green	Algae	450	0.00512	-	-	-	-	-	-	-	Jepson 1973
Cryptosporidium hominis	Protoz	30	0.07800	-	-	-	-	-	-	-	Johnson 2005
Cryptosporidium parvum	Protoz	7	0.31400	W	Wat	N	1	20	3	-	Oguma 2001
Cryptosporidium parvum	Protoz	20	0.11500	W	Wat	-	-	30	3	-	Zimmer 2003
Cryptosporidium parvum	Protoz	10	0.23030	W	Wat	N	1	30	3	-	Shin 2001
Cryptosporidium parvum	Protoz	50	0.04605	W	Wat	N	2	100	3	-	Craik 2001
Cryptosporidium parvum	Protoz	10	0.23220	W	Wat	N	1	40	3	-	Bukhari 2004
Cryptosporidium parvum	Protoz	5	0.45830	W	Wat	N	1	22	3	-	Morita 2002
Encephalitozoon intestinalis	Protoz	29	0.07830	W	Wat	N	2	50	-	-	``````
Encephalitozoon intestinalis	Protoz	15	0.15350	W	Wat	N	-	-	-	-	Huffman 2002
Encephalitozoon cuniculi	Protoz	43	0.05310	W	Wat	N	1	130	-	-	Marshall 2003
Encephalitozoon hellem	Protoz	80	0.02880	W	Wat	N	2	120	-	-	Marshall 2003
Giardia lamblia cysts	Protoz	50	0.04610	W	Wat	-	-	20	-	-	Campbell 2002
Giardia lamblia cysts	Protoz	3	0.92100	W	Wat	N	1	10	-	-	Shin 2005
Giardia lamblia cysts	Protoz	20	0.11500	W	Wat	N	1	40	-	-	Li 2007
Giardia muris cysts	Protoz	10	0.23020	W	Wat	N	2	10	-	-	Craik 2001
Giardia muris cysts	Protoz	7	0.34130	W	Wat	N	1	23	-	-	Hayes 2000
Protozoa	Protoz	80	0.02878	-	-	-	-	-	-	-	Jepson 1973
Protozoa	Protoz	240	0.00959	-	-	-	-	-	-	-	Summer 1962
Prions (scrapie)	Prion	24315	0.00009	-	-	-	-	-	-	-	Bellinger-Kawahara 1987
Prions (scrapie)	Prion	55618	0.00004	-	-	-	-	-	-	-	Alper 1967

Appendix D: UVGI Lamp Data and Ratings

LAMP	Mfr. Ref.	Output UV W	# of coils	Arclength cm	Dia. cm	Radius cm	Area cm^2	Surface I W/m^2	Rating $\mu W/cm^2$	Type MP/LP
782H10	AU	2.8	1	22.2	1.58	0.79	110	254	28	LP
782H20	AU	5.5	1	47.6	1.58	0.79	236	233	52	MP
782H30	AU	5.2	1	73	1.58	0.79	362	144	46	MP
782H30	AU	8.3	1	73	1.58	0.79	362	229	73	LP
782L10	AU	2	1	22.2	1.58	0.79	110	181	20	LP
782L10	AU	2.9	1	22.2	1.58	0.79	110	263	28	MP
782L10 (cc)	ATL	2.9	1	37.46	1.58	0.79	186	156	29	LP
782L20	AU	3.9	1	47.6	1.58	0.79	236	165	35	LP
782L20 (cc)	ATL	5.8	1	62.86	1.58	0.79	312	186	55	LP
782L25_1/2	AU	7.3	1	64.8	1.58	0.79	322	227	75	MP
782L30	AU	5.2	1	73	1.58	0.79	362	144	46	LP
782L30	AU	8.3	1	73	1.58	0.79	362	229	73	LP
782L30 (cc)	ATL	8.7	1	88.26	1.58	0.79	438	199	77	LP
782VH10 (cc)	ATL	2.9	1	37.46	1.58	0.79	186	156	29	LP
782VH20 (cc)	ATL	5.8	1	62.86	1.58	0.79	312	186	55	LP
782VH29	AU	5.7	1	70.8	1.58	0.79	351	162	50	LP
782VH29	AU	9.1	1	70.8	1.58	0.79	351	259	80	LP
782VH30 (cc)	ATL	8.7	1	88.26	1.58	0.79	438	199	77	LP
83A-1	IESNA	3.1	1	27.3	1.75	0.875	150	207	35	LP
84A-1	IESNA	4.1	1	62.8	1.3	0.65	256	160	46	MP
86A-45	IESNA	1.4	1	11.4	1.75	0.875	63	223	16	LP
87A-45	IESNA	4.3	1	26.7	1.75	0.875	147	293	47	LP
88A-45	IESNA	10.4	1	62.2	1.75	0.875	342	304	113	MP
93A-1	IESNA	1.9	1	29.2	1.3	0.65	119	159	21	LP
94A-1	IESNA	7.2	1	62.8	1.75	0.875	345	209	80	LP
AC4-100LL	UVS	280	1	420	1.8	0.9	2375	1179	1023*	MP
AC4-150LL	UVS	420	1	620	1.8	0.9	3506	1198	1065*	LP
AC4-25LL	UVS	80	1	120	1.8	0.9	679	1179	666*	LP
AC4-50LL	UVS	150	1	220	1.8	0.9	1244	1206	921*	LP
AGHO287T5L	LSI	6.5	1	20.6	1.6	0.8	104	628	70	LP
C24T6L (cc)	ATL	5	1	55.56	1.58	0.79	276	181	47	LP
C24T6VH (cc)	ATL	5	1	55.56	1.58	0.79	276	181	47	LP
CC12T6L (cc)	ATL	1.4	1	25.08	1.58	0.79	124	112	14	LP
CC12T6VH (cc)	ATL	1.4	1	25.08	1.58	0.79	124	112	14	LP
CC18T6L (cc)	ATL	3.2	1	40.32	1.58	0.79	200	160	32	LP
CC18T6VH (cc)	ATL	3.2	1	40.32	1.58	0.79	200	160	32	LP
CC36T6L (cc)	ATL	8.5	1	86.04	1.58	0.79	427	199	75	MP
CC36T6VH (cc)	ATL	8.5	1	86.04	1.58	0.79	427	199	75	LP
CC48T6L (cc)	ATL	11.2	1	116.52	1.58	0.79	578	194	98	LP
CC48T6VH (cc)	ATL	11.2	1	116.52	1.58	0.79	578	194	98	LP
G10T5_1/2H	AU	5.3	1	27.6	1.58	0.79	137	387	55	LP
G10T5_1/2L	AU	5.3	1	27.6	1.58	0.79	137	387	55	LP
G10T5_1/2VH	AU	5.3	1	27.6	1.58	0.79	137	387	55	LP
G10T51/2L	ATL	5.3	1	42.86	1.58	0.79	213	249	55	LP
G10T51/2VH	ATL	5.3	1	42.86	1.58	0.79	213	249	55	LP
G10T8	T-W	2.6	1	24.5	2.55	1.275	196	132	27	LP
G10T8	GE	1.9	1	33	2.55	1.275	264	72	19*	MP
G11T5	Philips	3	1	15.5	1.5	0.75	73	411	30	MP

Appendix D: UVGI Lamp Data and Ratings

LAMP	Mfr. Ref.	Output UV W	# of coils	Arclength cm	Dia. cm	Radius cm	Area cm^2	Surface I W/m^2	Rating $\mu W/cm^2$	Type MP/LP
G11T5	GE	2.2	1	22.63	0.63	0.3125	44	495	22.9	LP
G12T5_1/2L	AU	6	1	21.6	1.58	0.79	107	560	66	LP
G12T5_1/2VH	AU	6	1	21.6	1.58	0.79	107	560	66	LP
G12T6L	ATL	3.1	1	30.48	1.58	0.79	151	205	32	LP
G12T6VH	ATL	3.1	1	30.48	1.58	0.79	151	205	32	LP
G15T8	AU	3.6	1	36.5	2.54	1.27	291	124	38	LP
G15T8	ATL	4.8	1	43.6	2.55	1.275	349	137	49	MP
G18T6L	ATL	5.8	1	40.32	2.54	1.27	322	180	59	MP
G18T6L/U	ATL	5.8	2	21	2.54	1.27	168	346	59	LP
G18T6VH	ATL	5.8	1	40.32	2.54	1.27	322	180	59	LP
G18T6VH/U	ATL	5.8	2	21	2.54	1.27	168	346	59	MP
G20T10	GE	7.5	1	58	3.25	1.625	592	127	75.8	LP
G20T10	-	4.1	1	58.85	3.25	1.625	601	68	40*	MP
G20T10	-	4.2	1	58.85	3.25	1.625	601	70	41*	LP
G24T6L	ATL	8.5	1	55.56	2.54	1.27	443	192	82	LP
G24T6L/U	ATL	8.5	2	28.6	2.54	1.27	228	372	82	LP
G24T6VH	ATL	8.5	1	55.56	2.54	1.27	443	192	82	MP
G24T6VH/U	ATL	8.5	2	28.6	2.54	1.27	228	372	82	LP
G25T8	Philips	6.6	1	35.56	2.54	1.27	284	233	65.5	LP
G25T8	ATL	6.9	1	43.6	2.55	1.275	349	198	70.4	LP
G25T8(W)	AU	5	1	36.5	2.54	1.27	291	172	54	LP
G30T6L	ATL	11.2	1	70.8	2.54	1.27	565	198	101	LP
G30T6L/U	ATL	11.2	2	36.2	2.54	1.27	289	388	101	LP
G30T6VH	ATL	11.2	1	70.8	2.54	1.27	565	198	101	LP
G30T6VH/U	ATL	11.2	2	36.2	2.54	1.27	289	388	101	LP
G30T8	T-W	11.6	1	81.3	2.54	1.27	649	179	117	LP
G30T8	ATL	11.6	1	89.3	2.55	1.275	715	162	117	MP
G30T8(W)	AU	8.3	1	81.3	2.54	1.27	649	128	85	LP
G36T5L	Philips	13.9	1	75.9	1.5	0.75	358	389	181	LP
G36T5L	GE	12	1	86.55	1.5	0.75	408	294	109.5	LP
G36T6	AU	12.7	1	76.2	1.9	0.95	455	279	110	LP
G36T6H	AU	13.8	1	76.2	1.58	0.79	378	365	120	LP
G36T6L	LSI	13.8	1	76.2	1.5	0.75	359	384	176	MP
G36T6L	ATL	13.8	1	86.04	1.58	0.79	427	323	120	LP
G36T6L(W)	AU	13.8	1	76.2	1.58	0.79	378	365	120	LP
G36T6L/U	ATL	13.8	2	43.8	2.54	1.27	350	395	120	LP
G36T6VH	AU	15.2	1	78.7	1.58	0.79	391	389	124	MP
G36T6VH	ATL	13.8	1	86.04	1.58	0.79	427	323	120	LP
G36T6VH/U	ATL	13.8	2	43.8	2.54	1.27	350	395	120	LP
G37T6L	ATL	14.3	1	88.58	1.58	0.79	440	325	124	LP
G37T6VH	IESNA	14.3	1	78.5	1.58	0.79	390	367	130	LP
G37T6VH	ATL	14.3	1	88.58	1.58	0.79	440	325	124	LP
G40T10	T-W	11.5	1	119.8	3.25	1.625	1223	94	96*	LP
G40T10	GE	19.8	1	121.3	3.25	1.625	1238	160	200	LP
G48T6L	ATL	19.3	1	116.52	1.58	0.79	578	334	164	MP
G48T6L/U	ATL	19.3	2	59.1	2.54	1.27	472	409	164	LP
G48T6VH	ATL	19.3	1	116.52	1.58	0.79	578	334	164	LP
G48T6VH/U	ATL	19.3	2	59.1	2.54	1.27	472	409	164	LP

Appendix D: UVGI Lamp Data and Ratings

LAMP	Mfr. Ref.	Output UV W	# of coils	Arclength cm	Dia. cm	Radius cm	Area cm^2	Surface I W/m^2	Rating $\mu W/cm^2$	Type MP/LP
G4S11	AU	0.1	1	0.95	3.49	1.745	10	96	1.1	LP
G4S11	-	0.18	1	5.7	3.5	1.75	63	29	2*	LP
G4T4	AU	0.7	1	7.8	1.35	0.675	33	212	10	LP
G4T4/1	AU	1.1	1	15	1.3	0.65	61	180	12	MP
G4T5	ATL	0.8	1	8.1	1.55	0.775	39	203	8.3	MP
G4T5	GE	0.9	1	15.01	1.55	0.775	73	123	8.3	LP
G4T5	GE	0.8	1	15.01	1.5	0.75	71	113	8.3	LP
G4T5(W)	AU	0.5	1	6.3	1.58	0.79	31	160	5.4	LP
G55T8HO	GE	18	1	90.88	3.25	1.625	928	194	194	LP
G64T5L	AU	26.7	1	147.3	1.58	0.79	731	365	190	LP
G64T5L	ATL	25	1	157.16	1.58	0.79	780	320	200	MP
G64T5VH	AU	26.7	1	147.3	1.58	0.79	731	365	190	MP
G64T5VH	ATL	25	1	157.16	1.58	0.79	780	320	200	MP
G64T6	IESNA	25	1	147	1.9	0.95	877	285	200	LP
G64T6L	AU	25.5	1	147.3	1.9	0.95	879	290	208	LP
G67T5L	AU	25.6	1	152.5	1.58	0.79	757	338	205	LP
G67T5VH	AU	25.6	1	152.5	1.58	0.79	757	338	205	LP
G6T5	T-W	1.6	1	15.7	1.55	0.775	76	209	16.7	LP
G6T5	ATL	1.6	1	21.05	1.55	0.775	103	156	16.7	LP
G6T5	GE	1.7	1	22.63	0.63	0.3125	44	383	17.7	LP
G6T5(W)	AU	1	1	14	1.58	0.79	69	144	11	MP
G8T5	ATL	2.5	1	23.3	1.55	0.775	113	220	26	LP
G8T5	GE	2.3	1	30.25	0.63	0.3125	59	387	24	LP
G8T5(W)	AU	1.6	1	21.6	1.58	0.79	107	149	17	LP
GBX11/UVC	GE	3.6	2	21.5	1.5	0.75	101	355	33	LP
GBX13/UVC	GE	3.6	2	17	1.5	0.75	80	449	31	LP
GBX18/UVC/2G11	GE	5.5	2	22.5	1.5	0.75	106	519	51	LP
GBX36/UVC/2G11	GE	12	2	41.5	1.5	0.75	196	614	110	MP
GBX5/UVC	GE	1	2	8.5	1.5	0.75	40	250	9	LP
GBX55/UVC/2G11	GE	17	2	53.5	1.5	0.75	252	674	156	LP
GBX9/UVC	GE	2.4	2	14.5	1.5	0.75	68	351	22	LP
GCC369H	AU	2.4	1	22.9	1.58	0.79	114	211	23.7	LP
GCC369N	AU	1.6	1	22.9	1.58	0.79	114	141	16	LP
GHO287T5L	LSI	3.2	1	20.6	1.6	0.8	104	309	35	LP
GHO36T5/L/4PSE	ATL	28	1	75.5	1.5	0.75	356	787	260	LP
GHO36T5/VH/4PSE	ATL	28	1	75.5	1.5	0.75	356	787	260	LP
GHO64T5/L/4PSE	ATL	45	1	142.1	1.5	0.75	670	672	380	LP
GHO64T5VH/4PSE	ATL	45	1	142.1	1.5	0.75	670	672	380	LP
GPH212T5L	LSI	2.9	1	13.21	1.5	0.75	62	466	29.5	LP
GPH212T5L	ATL	2.3	1	21.2	1.5	0.75	100	230	24	LP
GPH212T5VH	ATL	2.3	1	21.2	1.5	0.75	100	230	24	LP
GPH287T5-H	IESNA	3	1	20	1.6	0.8	101	298	33	LP
GPH287T5L	LSI	3.2	1	20.57	1.5	0.75	97	330	35	LP
GPH287T5L	ATL	3.7	1	28.7	1.5	0.75	135	274	38	LP
GPH287T5LVH	ATL	3.7	1	28.7	1.5	0.75	135	274	38	LP
GPH287T5-VH	IESNA	3	1	20	1.6	0.8	101	298	33	LP
GPH330T5L/4	ATL	4.5	1	33	1.5	0.75	156	289	44	LP
GPH330T5VH/4	ATL	4.5	1	33	1.5	0.75	156	289	44	LP

Appendix D: UVGI Lamp Data and Ratings

LAMP	Mfr. Ref.	Output UV W	# of coils	Arclength cm	Dia. cm	Radius cm	Area cm^2	Surface I W/m^2	Rating $\mu W/cm^2$	Type MP/LP
GPH357T5L/4	ATL	5	1	35.7	1.5	0.75	168	297	51	LP
GPH357T5VH/4	ATL	5	1	35.7	1.5	0.75	168	297	51	LP
GPH435T5	LSI	9.6	1	35	1.5	0.75	165	582	88	LP
GPH436T5/HO/4C	LSI	14	1	29.2	1.5	0.75	138	1017	140	LP
GPH436T5/VH/HO/4PSE	ATL	13	1	36	1.5	0.75	170	766	120	LP
GPH436T5L	ATL	6.4	1	43.6	1.5	0.75	205	311	59	LP
GPH436T5L/HO/4PSE	ATL	13	1	36	1.5	0.75	170	766	120	LP
GPH436T5LHO/4P	LSI	8	1	36	1.5	0.75	170	472	75	LP
GPH436T5VH	ATL	6.4	1	43.6	1.5	0.75	205	311	59	MP
GPH450T5L/4	ATL	6.6	1	45	1.5	0.75	212	311	62	MP
GPH450T5VH/4	ATL	6.6	1	45	1.5	0.75	212	311	62	MP
GPH463T5L/4	ATL	6.9	1	46.3	1.5	0.75	218	316	63	LP
GPH463T5VH/4	ATL	6.9	1	46.3	1.5	0.75	218	316	63	LP
GPH620T5L/4	ATL	9.7	1	62	1.5	0.75	292	332	87	LP
GPH620T5VH/4	ATL	9.7	1	62	1.5	0.75	292	332	87	LP
GPH793T5L	ATL	12.8	1	79.3	1.5	0.75	374	343	112	LP
GPH793T5VH	ATL	12.8	1	79.3	1.5	0.75	374	343	112	LP
GPH810T5L/4	ATL	13.1	1	81	1.5	0.75	382	343	115	LP
GPH810T5VH/4	ATL	13.1	1	81	1.5	0.75	382	343	115	LP
GPH846T5/L/HO/4PSE	ATL	29	1	76.7	1.5	0.75	361	802	265	MP
GPH846T5/VH/HO/4PSE	ATL	29	1	76.7	1.5	0.75	361	802	265	LP
GPH846T5LHO/4P	LSI	17	1	76.71	1.5	0.75	361	470	165	LP
GPH893T5/L/HO/4PSE	ATL	30	1	81.5	1.5	0.75	384	781	270	LP
GPH893T5/VH/HO/4PSE	ATL	30	1	81.5	1.5	0.75	384	781	270	LP
GPH893T5LHO/4P	LSI	17	1	81.53	1.5	0.75	384	442	156	LP
GTL2	-	0.12	1	5.5	2	1	35	35	1.2	LP
GTL3	ATL	0.18	1	6.3	2	1	40	45	1.8	LP
GUL4	-	0.7	1	15	1.35	0.675	64	110	10	LP
LSI436T5	LSI	8	1	36	2	1	226	354	80	LP
LTC18W	SXX	5.5	2	17.2	1.25	0.625	68	814	51	LP
LTC24W	SXX	7	2	17.2	1.25	0.625	68	1036	65	LP
LTC36W	SXX	12	2	17.2	1.25	0.625	68	1777	110	LP
LTC55W	SXX	17	2	17.2	1.25	0.625	68	2517	156	LP
LTC95W	SXX	32	2	17.2	1.25	0.625	68	4738	304	LP
LTCPL11	SXX	3.6	2	12.5	1.25	0.625	49	733	33	LP
LTCPL5	SXX	1	2	12.5	1.25	0.625	49	204	9	LP
LTCPL7	SXX	1.8	2	12.5	1.25	0.625	49	367	16	LP
LTCPL9	SXX	2.4	2	12.5	1.25	0.625	49	489	22	LP
OZ4S11	AU	0.1	1	0.95	3.49	1.745	10	96	1.1	LP
OZ4T5	AU	0.6	1	15.2	1.58	0.79	75	80	6.5	LP
OZ6T5	AU	1.2	1	22.9	1.58	0.79	114	106	13	LP
OZ8T5	AU	1.8	1	21.6	1.58	0.79	107	168	19.5	MP
PL-L35W/TUV	Philips	11	1	22.7	0.9	0.45	64	1714	111*	LP
PL-L36W/TUV	Philips	12	1	41.75	0.9	0.45	118	1017	119*	MP
PL-L60W/TUV	Philips	17.5	1	41.75	0.9	0.45	118	1482	173*	MP
SA5000*	SA	16	1	43.18	1.8	0.9	244	655	158	MP
SPECIAL 1	Philips	34	1	46.7	1.8	0.9	264	1287	335	LP
TUV10W	Philips	2.2	1	33.15	2.8	1.4	292	75	22	LP

Appendix D: UVGI Lamp Data and Ratings

LAMP	Mfr. Ref.	Output UV W	# of coils	Arclength cm	Dia. cm	Radius cm	Area cm^2	Surface I W/m^2	Rating $\mu W/cm^2$	Type MP/LP
TUV115W	Philips	33.5	1	119.94	4.05	2.025	1526	220	300	LP
TUV115WVHO	Philips	38.8	1	119.94	4.05	2.025	1526	254	300	LP
TUV11W	Philips	2.2	2	42.42	0.9	0.45	120	183	22	LP
TUV11WPL-S	Philips	3.6	2	39.6	0.9	0.45	112	322	36	MP
TUV15W	Philips	4.7	1	43.74	2.8	1.4	385	122	47	MP
TUV16T5	Philips	5	1	22.86	1.5	0.75	108	464	46	MP
TUV16W	Philips	3.2	1	28.83	1.6	0.8	145	221	32	LP
TUV18W	Philips	5.5	2	39	0.9	0.45	110	499	90	LP
TUV18WPL-L	Philips	4.6	2	31.75	1.8	0.9	180	256	46	MP
TUV30W	Philips	11.2	1	89.46	2.8	1.4	787	142	102	MP
TUV36W	Philips	14	1	112.5	2.6	1.3	919	152	110	LP
TUV36WPL-L	Philips	12	2	73	0.9	0.45	206	581	90	LP
TUV4W	Philips	0.9	1	8.6	1.6	0.8	43	208	7	LP
TUV55W	Philips	18	2	178.92	0.9	0.45	506	356	163	LP
TUV55WHO	Philips	17	1	78.2	2.6	1.3	639	266	158	LP
TUV55WPL-L	Philips	17	2	94.65	1.8	0.9	535	318	290	LP
TUV59W	Philips	9	2	21.6	0.9	0.45	61	1474	92	LP
TUV6W	Philips	1.5	1	16.2	1.6	0.8	81	184	14	LP
TUV75W	Philips	26	1	119.94	2.8	1.4	1055	246	217	MP
TUV75WHO	Philips	25	1	112.5	2.6	1.3	919	272	213	LP
TUV8W	Philips	2.1	1	23.8	1.6	0.8	120	176	17	LP
TUV9WPL-S	Philips	2.4	2	25.8	0.9	0.45	73	329	24	LP

AU = American Ultraviolet
ATL = Atlantic Ultraviolet
UVS = UV Systec
SXX = Shangyu Xin Xin

(cc) = Cold cathode
*(computed estimate)
**(output varies)

MP = Medium Pressure
LP = Low Pressure

APPENDIX E: C++ Source Code for Lamp UV Field Average Irradiance

```
// Author's note: This source code is the same as the source code provided in Kowalski
(2001) and Kowalski (2003) except that the UV lamp(s) in this version may be located at
any position (x1, y1, z1, x2, y2, z2) where the coordinates represent the endpoints of the
lamp. In this version, the x1 coordinate need not be zero, but may be any value.

// Global variables and arrays (these values can be output to a text file)

double Average;                         // Average UV Irradiance
double DirectField[51][51][101];        // Direct Irradiance Field
double DistanceMtx[51][51][101];        // matrix of distances to lamp axis
double PositionMtx[51][51][101];        // matrix of position along lamp axis

// The following values can be set with a separate input routine or text file

int NUMLAMPS = 1;               // number of lamps in system (set value to 1 or more)
double SurfInt[1] = 10000.0;            // Lamp surface irradiance for lamp #1, μW/cm2,
        surface irradiance may be computed from lamp wattage (see Chapter 7),
        (set value)
double arclength[1] = 35.0;             // Lamp arclength for lamp #1, cm (set value)
double radius[1] = 1.0;                 // radius of lamp # 1, cm (set value)

brun(){         // this routine calls the computational subroutines in C++ and
                // computes the direct irradiance field for all lamps in an enclosure
                // and fills the matrix DirectField[][][] with the irradiance values
DirectIntField();       // Compute the average irradiance
AverageDirect();        // the result, Average, can be printed here or output to a file
}

void DirectIntField()
{       // Computes 50x50x100 UV Irradiance Matrix of Direct Irradiance Field
   int i, j, k, l;
   double tempsum = 0.0, x, paxis, db;
   for (i=0; i<=50; i++){
      db=0.0;
      for (j=0; j<=50; j++){
         for (k=0; k<=100; k++){
            for (l=0; l<NUMLAMPS; l=l+1) {
               x = Distance(i,j,k,l);           // Compute distance x to lamp axis
               DistanceMtx[i][j][k]=x;
               paxis = Position(i,j,k,l);       // Compute position on lamp axis
               PositionMtx[i][j][k]=paxis;
               if (paxis < arclength[l]){       // Is it within lamp arclength?
                        // Compute Intensity within Lamp arclength
                  tempsum = Intensity(SurfInt[l],arclength[l],radius[l],x,paxis);
               }
               else {    // Compute Intensity beyond Lamp end
                  db = paxis-arclength[l];
                  tempsum = IBeyondEnds(SurfInt[l],arclength[l],radius[l],x,db);
               }
                  // Add irradiances for all lamps
               DirectField[i][j][k] = DirectField[i][j][k] + tempsum;
                tempsum = 0.0;
            }
```

```
            }
        }
    }
}


double Distance(int i, int j, int k, int l)
{           //  Compute shortest Distance to Lamp Axis
    double xi, yj, zk;
    xi = i;
    yj = j;
    zk = k;
    double x = xi*xincr;
    double y = yj*yincr;
    double z = zk*zincr;
    double dist = PointLine(x, y, z, l);
    return dist;
}

double PointLine(double x, double y, double z, int l)
{           //  Compute Distance from a Point to a Line (lamp axis)
        double x1=x-lampx1[l];
        double y1=y-lampy1[l];
        double z1=z-lampz1[l];
        double x2=lampx2[l]-lampx1[l];
        double y2=lampy2[l]-lampy1[l];
        double z2=lampz2[l]-lampz1[l];
        double dist, DotProd, a;
        double p1=x1*x1+y1*y1+z1*z1;
        double p2=x2*x2+y2*y2+z2*z2;
        if (p1*p2>0){
            DotProd = (x1*x2+y1*y2+z1*z2)/sqrt(p1*p2);
            a = acos(DotProd);
            dist=fabs(sin(a))*sqrt(p1);
        }
        else {
            dist = 0;
        }
    return dist;
}

double Position(int i, int j, int k, int l)
{           // Compute Position along lamp axis
        double xi, yj, zk, p1, p2, posit, p3, p4, a, x;
        double DotProd, y, z, x1, y1, z1, x2, y2, z2;
        double pc, pa, pd, p5, posit1, posit2;
        xi = i;
        yj = j;
        zk = k;
        x = xi*xincr;
        y = yj*yincr;
        z = zk*zincr;
        posit = 1;
        x1=x-lampx1[l];
        y1=y-lampy1[l];
        z1=z-lampz1[l];
```

```
        x2 = lampx2[l]-lampx1[l];
        y2 = lampy2[l]-lampy1[l];
        z2 = lampz2[l]-lampz1[l];
        p1 = x1*x1+y1*y1+z1*z1;
        p2 = x2*x2+y2*y2+z2*z2;
        pc = x1*x2+y1*y2+z1*z2;
        pa =p1*p2;
        if (pa>0){
           DotProd = pc/sqrt(pa);
           a = acos(DotProd);
           posit1 = cos(a)*sqrt(p1);
        }
        else {
           posit1 = 0.000001;
        }
        x1=x-lampx2[l];
        y1=y-lampy2[l];
        z1=z-lampz2[l];
        x2 = lampx1[l]-lampx2[l];
        y2 = lampy1[l]-lampy2[l];
        z2 = lampz1[l]-lampz2[l];
        p3 = x1*x1+y1*y1+z1*z1;
        p4 = x2*x2+y2*y2+z2*z2;
        pd = x1*x2+y1*y2+z1*z2;
        p5 =p3*p4;
        if (p5>0){
           DotProd = pd/sqrt(p5);
           a = acos(DotProd);
           posit2 = cos(a)*sqrt(p3);
        }
        else {
           posit2 = 0.000001;
        }
        posit = max(posit1,posit2);
     return posit;
}

double Intensity(double IS, double arcl, double r, double x, double l)
{          // Compute Irardiance Field
           // IS=Surface Irradiance, arcl=arclength, r=radius,
            // x=distance from axis, l = distance along axis
       double intense;
       double VF, VF1, VF2;
              // Compute VF Lamp segment 1
        VF1 = VFCylinder(l,r,x);
              // Compute Lamp segment 2
        VF2 = VFCylinder(arcl-l,r,x);
              // Total VF for Lamp
        VF = VF1 + VF2;
              // Compute intensity at the point
        intense = IS*VF;
        return intense;
}

double IBeyondEnds(double IS, double arcl, double r, double x, double db )
{          // Compute Irradiance field beyond the ends of the lamp
```

```
            // IS=Surface Irradiance, arcl=arclength, r=radius
            // x=distance from axis, db=distance beyond lamp end
        double intense;
        double VF, VF1, VF2;
          VF1 = VFCylinder(arcl+db,r,x);       // Compute Lamp + Ghost Lamp segment
          VF2 = VFCylinder(db,r,x);  // Compute Ghost Lamp segment
         VF = VF1 - VF2;     // Compute Lamp VF
         intense = fabs(IS*VF);         // Compute irradiance at the point
         return intense;
}

double VFCylinder(double l, double r, double h)    // View Factor #15 per Modest (1993)
{               // l=length, r=radius, h=height above axis
        double H, L, X, Y, p1, p2, p3, VF;
        if (h<r) h=r+0.000001;  // Not inside lamp
        H = h/r;
        L = l/r;
        if (L==0) L=0.000001;
        if (H==1) H=H+0.000001;
        X = (1+H)*(1+H)+L*L;
        Y = (1-H)*(1-H)+L*L;
                // Compute Parts of View Factor
        p1 = atan( L/sqrt(H*H-1) )/L;
        p2 = (X-2*H)*atan( sqrt( (X/Y)*(H-1)/(H+1) ))/sqrt(X*Y);
        p3 =  atan( sqrt((H-1)/(H+1)) );
        VF = L*(p1+p2-p3)/(Pi*H);
        return VF;

}

double AverageDirect()
{           // compute average irradiance field
    double total = 0;
    double Avg = 0;
    for (int i=0; i<=50; i++)
        for (int j=0; j<=50; j++)
            for (int k=0; k<=100; k++)
                total = total + DirectField[i][j][k];
    Average = total/(51*51*101);
    return Avg;
}
```

NOTE: For the complete source code implementation, which includes reflectivity subroutines for diffuse surfaces, see Kowalski (2001). For specular reflectivity modeling, see Kowalski et al (2005).

References and Additional Information:

Kowalski WJ, Bahnfleth WP. 2000. Effective UVGI system design through improved modeling. ASHRAE Transactions 106(2):4-15.

Kowalski WJ. 2001. Doctoral Thesis -- Design and optimization of UVGI air disinfection systems [PhD]. State College: The Pennsylvania State University.

Kowalski WJ. 2003. Immune Building Systems Technology. New York: McGraw-Hill.

Kowalski WJ, Bahnfleth WP, Mistrick RG. 2005. A specular model for UVGI air disinfection systems. IUVA News 7(1):19-26.

Appendix F: Ultraviolet Material Reflectivities (UVC/UVB Range)

MATERIAL	ρ %	MATERIAL	ρ %	MATERIAL	ρ %
ePTFE (tm WLGore)	99+	Nickel	37-38	Tin	16
Spectralon (PTFE)	95+	Steel	37	Carborundum	14.5
Smoked magnesium oxide	93	Zinc	37	Tantalum	13
Aluminum, etched	88	Cadmium	34	Tungsten	13
Evaporated aluminum	87	S.W. white Decotint paint	33	Kalsomine white water paint	12
Alzak sheet aluminum, brightened	87	Ivory wallpaper	31	Medusa cement	11
Alzak sheet aluminum	84	Pink figured wallpaper	31	Alabastine white water paint	10
Magnesium oxide	81	Speculum	30	White baked enamel	9
Magnesium carbonate (commercial)	81	Bleached cotton, white cotton	30	White oil paints (5-10)	8
Aluminum - sputtered on glass	80	Magnesium	29	Lithopone	8
Zirconium oxide, C.P.	78	Tin plated steel	28	Wall tiles	7-8
Pressed calcium carbonate	78	Stainless steel (20-30)	28	Black paint	7
Pressed magnesium oxide	77	Tin plated steel	28	Brass	7
Calcium carbonate	75	Palladium	28	Brown wrapping paper	7
Magnesium carbonate	75	Copper	25-31	Titanox C	7
Aluminum - treated surface	74	Lead	27	Titanium dioxide	7
Aluminum foil	73	Ivory figured wallpaper	26	Titanium oxide	6
Silicon	62-73	Molybdenum	25	AZO photo paper, exp. black	6
Aluminum hydroxide	67	White paper	25	Celluloid	6
Aluminum paint	65	White blotting paper	25	Pongee silk	6
Barytes	65	Magnalium	19	Brown baked enamel	6
Basic carbonate white lead (Dutch)	62	Antimony	17-32	Casein vehicle	6
New plaster	58	AZO photo paper, unexposed	24	Zinc sulfide	6
Galvanized duct - smooth	57	Tellurium	23	Titanox B	6
Aluminum oxide	55	Silver	22-23	Lead titanate	6
China clay	54	Chromium	16-31	Flat black Egyptian lacquer	5
Galvanized duct - rough	53	Gold	23	Lithopone	5
Aluminum - untreated surface	50	White water paint	23	Zinc oxide in clear lacquer	5
Basic sulfite white lead	48	White wallpaper	22	Black lacquer paint	5
White wall plaster (40-60)	46	Bismuth	22	Zinc oxide paint	5
Stellite	46	Water paints (10-30)	20	White porcelain enamel	4.7
Diatomaceous silica (Celite 10)	45	Concrete	19 (max)	Wood	4-5
Chromium	44-45	Brownish figured wallpaper	18	Lantern slide glass	4
Cobalt	42	Tungsten	18	Glass	4
Zirconium oxide (commercial)	41	Selenium	18	China clay	4
Stellite	41	Linen	17	Zinc oxide casein paint	4
Platinum	40	Fluorescent lamp phosphors	17	35% leaded zinc oxide	4
AZO photo paper, white back	39	Antimony oxide	17	Pressed zinc oxide	2.5-3
Chrome steel	39	Carbon	16	Lead-free zinc oxide	3
Rhodium	38	Duralumin	16	Open air	~0

See Section 6.4 in Chapter 6 for References

Appendix G: UVGI Rating Values (URV)

URV	Dose J/m^2	Dose $\mu W\text{-}s/cm^2$	Mean Dose, J/m^2	Notes
1	0.01	1	0.055	
2	0.10	10	0.15	
3	0.20	20	0.25	
4	0.30	30	0.4	
5	0.50	50	0.63	
6	0.75	75	0.88	
7	1.0	100	1.25	
8	1.5	150	2	
9	2.5	250	3.75	
10	5	500	7.5	Normal UV System Design Range
11	10	1000	12.5	
12	15	1500	17.5	
13	20	2000	25	
14	30	3000	35	
15	40	4000	45	
16	50	5000	55	
17	60	6000	70	
18	80	8000	90	
19	100	10000	150	
20	200	20000	250	
21	300	30000	350	
22	400	40000	450	
23	500	50000	750	
24	1000	100000	1500	
25	2000	200000	-	

NOTE: URV 21 - 25 are newly appended URV definitions