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Sensitivity of Bacteria, Protozoa, Viruses, and Other Microorganisms to Ultraviolet Radiation

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Data concerning the sensitivity of various organisms to ultraviolet (UV) radiation exposure are very important in the design of UV disinfection equipment. This review analyzes fluence data from almost 250 studies and organizes the data into a set of recommended fluence values for specific log reductions and an appendix containing all the collected data.

Key words: algae; bacteria; log reduction; protozoa; spores; ultraviolet; ultraviolet radiation; viruses.

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1. Introduction

This paper represents the third revision of a compilation that goes back to 1999. The original compilation was an internal document of Trojan Technologies [1]. The first revision was published in 2006 [2], and the second revision was published in 2016 [3]. Data from the previous reviews have been included here. In addition, data from the past 5 years (up to March 2021) have been added. Two other reviews of the sensitivity of microorganisms to ultraviolet (UV) radiation have been published elsewhere [4, 5].

Tables A1–A5 (in Appendix A) present, to the best of our knowledge, a summary of all peer-reviewed fluence-response data for UV exposure of various microorganisms that are pathogens, indicators, or organisms encountered in the application, testing of performance, and validation of UV disinfection

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technologies. The tables reflect the current state of knowledge, but they also include the variation in technique and biological response that currently exists in the absence of standardized protocols (see Refs. 6 and 7). Most of the data are from studies of microorganisms suspended in water; however, there are a few entries for microorganisms on surfaces or in air. Users are encouraged to review the original referenced publication for more details on the experimental protocols before they use the data. The references from which the data were abstracted must be carefully read to understand how the reported fluences were calculated and the assumptions and procedures used in the calculations.

In most cases, the data were generated from low-pressure (LP) monochromatic mercury arc lamp sources for which the lamp fluence rate (irradiance) can be measured empirically and multiplied by exposure time (in seconds) to obtain an incident fluence onto the sample being irradiated. However, earlier data do not always contain the correction factors that are now considered standard practice in order to determine the average fluence delivered to the microorganisms within the irradiated sample [6, 7]. Such uncorrected data are marked and should be considered as upper limits, since the necessary corrections have not been made. Some data are from polychromatic medium-pressure (MP) mercury arc lamps, and in some cases, both lamp types were used. In some cases, filtered polychromatic UV light was used to achieve a narrow band of irradiation around 254 nm. There are also cases where narrow-band light sources, such as UV light-emitting diodes (LEDs) and excilamps (lamps that emit UV radiation when an excited complex, *e.g.*, $KrCl^*$ or Xe_2^*, dissociates), have been used. In those cases where the UV exposure was at wavelengths other than 254 nm, the reported fluences have been multiplied by a germicidal factor (GF), defined as the UV sensitivity of a microorganism at wavelength λ normalized to 1.00 at 254 nm. This allows for the fluences to be compared with those using an LP UV lamp at 254 nm. If an action spectrum is available, the GFs were obtained from published action spectra. If no action spectrum is available, the GFs were taken from the relative absorbance of DNA. All GFs were obtained from the review by Bolton [8] ,except for a few cases where GF values were based on recent data. Note that the GF correction is limited because light sources such as the 222 nm excilamp and UV-LEDs have a significant bandwidth.

None of the data incorporated any effect of photorepair processes [9]. Only the response to the inactivating fluence is documented.

It is the intention of the authors and sponsors to maintain this table, with periodic updates. Recommendations for inclusion in the tables, along with the reference sources, should be sent to the authors. The recommended selection criteria for inclusion are the same as those used in the collection of the data in these tables. These criteria are:

1. Data must already be published in a peer-reviewed journal or other peer-reviewed publication media. Some exceptions have been allowed where data are only available in non-peer-reviewed papers.
2. For the publications where an LP or MP UV lamp are used as the UV source, the calculated fluence should usually be determined by using a quasi-collimated beam apparatus; however, for other UV sources, this criterion was not strictly followed, and such cases are noted.
3. Ideally, the fluence rate (irradiance) should have been measured with a recently calibrated radiometer, and when this has not been done, a well-characterized organism should be run as a reference to provide a comparison with the literature values to substantiate that the radiometer is within calibration.
4. The publication from which the data are abstracted should describe the experimental procedures, including collimated beam procedures, fluence calculation procedures along with any assumptions made, organism culturing procedures, and enumeration and preparation for experiments.
5. Ideally, as noted above, the protocol published in Ref. [6] or the recently published International Ultraviolet Association (IUVA) Protocol [7] should be followed. In cases where this protocol has not been followed, notes to that effect have been provided.

6. In some cases, data are provided using a pseudo-monochromatic light source (*e.g.*, UV-LED or excilamp) at wavelengths other than 254 nm. These fluence values have been multiplied by the appropriate GF (see above), so that they can be compared with data obtained using an LP lamp. The GF used is listed in the Notes column of the tables (that is, to recover the value reported in the original reference, divide the value in the table by the GF in the Notes column).
7. Responses should be determined over a range of fluences, that is, a complete fluence-response curve is preferred to a single fluence-response measurement.

These criteria will be applied strictly for future editions of these tables.

For the users of these tables, the following points can be helpful in understanding the information provided:

- In some papers, the authors used different methods for enumeration of their selected microorganism, and based on that, they reported different fluence responses in their work compared with the work of others. Where this has happened for a specific paper, a brief description of the implemented method is provided within the box containing the name of the tested microorganism.
- For the studies with UV sources other than an LP lamp (*e.g.*, filtered MP lamps, UV-LEDs, excilamps), the full width at half maximum (FWHM) of wavelength distribution around the peak wavelength is usually about 10–12 nm, except for the tunable laser, where the bandwidth is less than 1 nm.
- Where the authors have reported kinetic models based on their experimental data, these models were used in fluence calculations for these tables. Where model fits were not provided, the fluence reported for each specific log reduction number was extracted by graphic linearization (World-Wide-Web plot digitizer software) between two adjacent experimental data points in the fluence range.
- In some cases, fluence-response curves have been determined at several wavelengths, so that an action spectrum can be determined. These cases are noted as “action spectrum”; however, only data for wavelengths near 254 nm are included in the tables. Data for other wavelengths can be obtained from the cited reference.
- The reader should be aware that for a given microorganism, there is a data spread even after the selection criteria have been applied. Some studies have applied a Bayesian statistical analysis (*e.g.*, see Refs. [10, 11]) to obtain an average fluence-response curve and 95 percentile limits. Some of the factors that could affect the reported data are: the medium (*e.g.*, drinking water or wastewater), differences in the nutritional state of the cells being assayed, the presence of particles because of a failure to fully disperse cells following preconcentration for the collimated beam assay, *etc*.
- For a given microorganism, the fluence-response curve can depend markedly on the strain examined. This is why studies of a given strain have been grouped together.
- Note that the data in the tables below originate from highly controlled protocols usually using defined media and culture methods, irradiation methods, *etc*. These data are useful when validating UV technologies and envisioning regulations; however, as water quality, growth-phase state, particle content, and a number of other factors can impact microbe responses to disinfection in real environmental samples or processed water, such real waters should be used for site-specific assessments of UV disinfection, and design specification should benefit from the results of assays using these site-specific waters.
- In some cases, the quality of the data was questionable and did not meet some of the selection criteria listed above. In these cases, the data entries are in italics.
- In some cases, errors are given; these are usually at the 95 % confidence level

These tables can be used as a helpful document for understanding the fluence responses of different microorganisms at various wavelengths, with different UV sources; however, if more details are important for the users of these data, they must read the reference provided for each study.

Throughout this review, fluence rate and irradiance (units mW cm^{-2}) are used interchangeably, since they are virtually identical in a quasi-collimated beam apparatus. The term fluence (in units of mJ cm^{-2}) is used, which is the proper term [see Ref. [12] for a recommended set of terms and definitions] rather than "UV dose," which was used in earlier revisions of this document; however, it should be noted that the term UV dose is still widely used. Finally, it is noted that in Europe and other parts of the world, the units W m^{-2} for irradiance or fluence rate and J m^{-2} for fluence (UV dose) are more commonly used; the conversions are 1 mW cm^{-2} = 10 W m^{-2} and 1 mJ cm^{-2} = 10 J m^{-2}.

The data in the tables are for specific log reductions, where log reduction = 1, 2, 3, 4, and 5 for mean 90 %, 99 %, 99.9 %. 99.99 %, and 99.999 % reduction, respectively. Log reduction is defined as $\log_{10}(N_0/N)$, where N_0 is the initial viable microorganism count, and N is the final value after UV exposure.

2. Recommended Tables

In this review, for the first time, we have provided a table of recommended values, with the complete data set in Appendix A. The criteria for selecting recommended values were:

- Among various studies of a given microorganism/strain, a certain publication exhibited a very careful analysis that was deemed reliable.
- In some cases, data are available from a very large data set of fluence-response curves. In these cases, the entry in the recommendation table is highlighted in boldface type. These cases should be considered as *standard* values for that microorganism/strain.

Five tables of recommended values (Tables 1–5) cover spores, bacteria, protozoa, viruses, and algae and other large microorganisms.

Table 1. Recommended fluences for multiple log reductions for various spores.

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation						
Spore	Lamp Type	1	2	3	4	5	Notes	Reference
Aspergillus niger								
ATCC 16404	LP	122	226	293				[13]
Bacillus anthracis Sterne	LP	23	30					[14]
Bacillus atrophaeus	LP	10	16	26	39			[15]
Bacillus cereus T	LP	23	30	35	40			[14]
Bacillus pumilus								
ATCC 27142	LP	87	189					[16]
Bacillus subtilis								
ATCC 6633[a]	**LP**	**22 ± 6**	**36 ± 7**	**49 ± 9**	**62 ± 11**	**75 ± 11**		[17]
Encephalitozoon intestinalis	LP	2.8	5.6	8.4				[18]

[a]Data should be considered as *standard* values for the microorganism/strain.

Table 2. Recommended fluences for multiple log reductions for various bacteria.

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation							
Bacterium	Lamp Type	1	2	3	4	5	6	Notes	Reference
Actinobacter baumannii									
NCTC 12156	LP	0.6	1.8	3.3	4.8				[19]
Citrobacter diversus	LP	5	7	9	11	13			[20]
Citrobacter freundii	LP	5	9	13					[20]
Escherichia coli									
ATCC 11229	LP	4.1 ± 3.2	5.2 ± 3.3	6.2 ± 3.7	7.6 ± 4.4	8.6 ± 4.8	7.8		[21–24]
ATCC 25922	LP	6	6.5	7	8	9	10		[21]
ATCC 29425	LP	5.4	8.5	20					[25]
B ATCC 13033	LP	1.2	3	4.7	6.5	8.2	10		[15]
CGMCC 1.3373	LP	3.1	5.9	8	13				[26]
IFO 3301	LP	3.7	5.5	6.7	7.3	9.7			[27]
K12 ATCC 29425	LP	4 ± 3	7.3	9.4	14				[16, 28]
K12 IFO 3301	LP	2.0 ± 0.6	4	6	8				[29, 30]
NCTC 12241 – Antibiotic sensitive	LP	0.9	3.3	4.3	5.4	6.4			[31]
NCTC 13400 – Antibiotic resistant	LP	0.4	0.8	1.3	1.9	2.6			[31]
O157: H7 CCUG 29193	LP	3.5	4.7	5.5	7				[23]
O157: H7 CCUG 29197	LP	2.5	3	4.6	5	5.5			[23]
O157: H7 CCUG 29199	LP	0.4	0.7	1	1.1	1.3	1.4		[23]
O25: K98: NM	LP	5	7.5	9	10	12			[23]
O50: H7	LP	2.5	3	3.5	4.5	5	6		[23]
O78: H11	LP	4	5	5.5	6	7			[23]
OP50	LP	2	4.4	6.7	9.1				[32]
wild type	LP	4.4	6.2	7.3	8.1	9.2			[23]
Klebsiella pneumoniae	LP	5	7	10	12				[20]
Legionella longbeachae									
ATCC 33462	LP	1.4	3	4.7	6.3				[33]
Legionella pneumophila									
ATCC 33152	LP	1.7 ± 0.4	3.2 ± 0.5	4.6 ± 0.7	6 ± 1	8			[27, 33, 34]
ATCC 33823	LP	1.7	3.1	4.5	5.8				[33]
Sero group 1	LP	1.7	2.9	4.2	5.4				[33]
Sero group 8	LP	1.8	3.3	4.7	6.1				[33]
Mycobacterium terrae									
ATCC 15755	LP	3.8 ± 1.3	9.3	16					[35, 36]

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation							
Bacterium	Lamp Type	1	2	3	4	5	6	Notes	Reference
Pseudomonas aeruginosa									
ATCC 10145	LP	2.8	5.5	7	9.3				[27]
ATCC 15442	LP	1.6	3	4.8	8				[28]
NCTC 13437 – Antibiotic resistant	LP	0.7	1.5	2.3	6				[31]
Pseudomonas luteola									
Trimethoprim resistant HPC	LP	1.2	2.8	4.6	6.7				[31]
Salmonella typhimurium									
LT2 SL3770	LP	4	5.7	7.8				Action spectrum	[37]
LT2	LP	3.4	4.6	5.7	7.3			Action spectrum	[38]
Staphylococcus aureus	LP	2.1	3.2					Action spectrum	[39]
Vibrio harveyi	LP	5.2	6.9	8.9					[38]

Table 3. Recommended fluences for multiple log reductions for various protozoa.

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation						
Protozoan	Lamp Type	1	2	3	4	5	Notes	Reference
Acanthamoeba castellanii								
CCAP 15342 (life stage: trophozoites)	LP	32	52	72				[33]
CCAP 15342 (life stage: cysts)	LP	45	75	91	125			[33]
***Acanthamoeba* spp.**								
155 (life stage: trophozoites)	LP	28	31	66	71			[33]
155 (life stage: cysts)	LP	34	67	99				[33]
Cryptosporidium hominis [cell culture infectivity assay using HCT-8 cells (CCL-244) & MDBK cells]	LP	3	5.8					[40]
Cryptosporidium parvum								
HNJ-1 [mouse infectivity assay (SCID mice)]	LP	<0.7	<1.4	2.2				[30]
	LP	1.2 ± 0.6	2.4 ± 1.4	6.5	7.4	8		[38, 41–46]

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation						
Protozoan	Lamp Type	1	2	3	4	5	Notes	Reference
[mouse infectivity assay (neonatal CD-1 mice)]	LP	2.4	<5	5.2	9.5			[47]
Giardia lamblia								
(gerbil infectivity assay)	LP	0.9	1	1.8	0.8			[48, 49]
Giardia muris								
(mouse infectivity assay)	LP	1.7	2.3	3.3	2.3			[49–51]
Vermamoeba vermiformis								
CCAP 15434 /7A (life stage: trophozoites)	LP	11	19	26	34			[33]
CCAP 15434/7A (life stage: cysts)	LP	17	38	54	78			[33]
195 (life stage: trophozoites)	LP	10	17	24	32			[33]
195 (life stage: cysts)	LP	32	60	76	110			[33]

Table 4. Recommended fluences for multiple log reductions for various viruses.

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation							
Virus	Host	Lamp Type	1	2	3	4	5	6	Notes	Reference
Adenovirus										
Type 2		LP	37 ± 12	71 ± 11	108 ± 15	145 ± 24	156	235		[16, 52–65]
Type 4 ATCC VR-1572	PLC/PRF/5 ATCC CRL-8024	LP	10	34	69	116				[66]
Type 5		LP	53 ± 23	92 ± 35	141 ± 45					[29, 63, 67]
Type 40		LP	57	99	138	130				[68, 69]
Type 41		LP	59 ± 38	116 ± 57	167	222				[63, 70]
B40-8 (phage)	*Bacteroides fragilis*	LP	12 ± 6	18 ± 6	23	29 ± 6	35	41		[21, 24]
Calcivirus feline										
ATCC VR-782	CRFK cells[a]	LP	5	14	21	28 ± 25	39			[68, 71]
Coronavirus										
HCoV-229E	Human lung fibroblast MRC-5 cell line (ATCC CCL-171)	LP	1.7	3.2						[72]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation							
Virus	Host	Lamp Type	1	2	3	4	5	6	Notes	Reference
Coxsackievirus										
B3	BGM cell line[b]	LP	8	16	25	33				[52]
B4	BGM cell line	LP	7	13	18	24	29			[59]
B5	BGM cell line	LP	8.3	16	24	36				[52, 73]
Echovirus										
I	BGM cell line	LP	8	17	25	33				[52]
II	BGM cell line	LP	7	14	21	28				[52]
12	Fetal rhesus monkey kidney cell FRhK-4, ATCC CRL-1688	LP	8	13	18	28	40			[71]
Hepatitis										
A HM175	FRhK-4 cell	LP	4	8	12	16				[73]
HEV-p6-kernow	HepG2/C3A cells ATCC CRL-10741	LP	6.5	12	18	23	30		(5)	[74]
JC polyomavirus										
Mad-4	SVG-A cells	LP	123	124	171					[56]
MS2 coliphage										
ATCC15977-B1[a]	***E. coli* Hfr (*c*-3000)**	**LP**	**17 ± 2**	**39 ± 4**	**65 ± 8**	**96 ± 12**	**130 ± 18**	**17 ± 2**		[75]
Murine hepatitis virus (MHV)										
A59	DBT cells	LP	1	2.1	3.2					[72]
Murine norovirus										
CW3	RAW 264.7 macrophags ATCC TIB-71	LP	10	15	22	27	30			[71]
Myoviridae	*E. coli* C	LP	1.8	3.6	5.1	6.7	8.5			[59]
PHI 6	*Pseudomonas syringae*	LP	30	71						[72]
PHI X 174										
(phage)		LP	2.7 ± 1.1	5.2 ± 2.1	7.6 ± 3.3	9 ± 2	12	14 ± 13		[20, 21, 24, 73, 76, 77]
Poliovirus										
Type 1	BGM cell line	LP	8.4 ± 4.4	17 ± 6	24 ± 13	31				[52, 59]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation							
Virus	Host	Lamp Type	1	2	3	4	5	6	Notes	Reference
PRD-1 (Tectiviridae)										
ATCC BAA-769-B1	*Salmonella typhimurium* Lt2	LP	18	50	81	108	138			[59]
	Salmonella typhimurium Lt2	LP	10	17	24	33				[76, 78]
Qbeta										
ATCC 15597-B1	*E. coli* K12 A/*l*(F+) ATCC 10798	LP	11	24					Action spectrum	[27]
ATCC 23631-B1	*E. coli* ATCC 23631	LP	8	19 ± 13	28	40				[69, 79]
phage	*E. coli* K12 A/*l*(F+)	LP	11 ± 6	25 ± 19	38 ± 32	55				[29, 80]
Rotavirus										
SA-11		LP	7.5 ± 6.4	15	25	38				[21, 73]
Siphoviridae	*E. coli* C	LP	1.8	3.6	5.7	7.5	9.3			[59]
T1	*E. coli* CN13	LP	*N/A*	*N/A*	*N/A*	*13*				[76]
T1UV										
HER 468[c]	***E. coli* CN13 ATCC 700609**	**LP**	**4.6 ± 0.4**	**9.5 ± 0.9**	**15 ±2**	**20 ± 2**	**26 ± 3**			[75]
T4	*E. coli*	LP	1.1	2	3	4	6.7			[81]
T7										
ATCC BAA-1025-B2[a]	***E. coli* BL21**	**LP**	**1.3 ± 0.4**	**3.4 ± 1.0**	**6.3 ± 1.7**	**10 ± 3**	**14 ± 4**			[75]
T7m										
ATCC 11303-B38	*E. coli* B ATCC 11303	LP	N/A	3.4					Action spectrum	[79]
V_1 (Podoviridae)	*E. coli* WG5	LP	3.1	5.9	8.8					[59]

[a]Crandell-Rees Feline Kidney Cell
[b]Buffalo Green Monkey cells
[c]Data should be considered as standard values for the microorganism/strain.

Table 5. Recommended fluences for multiple log reductions for various algae and other microorganisms.

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation						
Microorganism	Lamp Type	1	2	3	4	5	Notes	Reference
Ascaris suum								
Intact eggs from worms	LP	100	328 + tailing					[82]
Decorticated eggs from worms	LP	30						[82]
Microcystis aeruginosa								
PCC7806	LP	*10*	*28*	*>60*				[83]

Appendix A—Summary of Collected Fluence-Response Data

Table A1. Fluences for multiple log reductions for various spores.

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation							
Spore	Lamp Type	1	2	3	4	5	Protocol?	Notes	Reference
Aspergillus brasiliensis (previously known as ***Aspergillus niger***) ATCC 16404 (dark culture)	LP	122	226	293			yes		[13]
Aspergillus fumigatus									
	UV-LED 255 nm	4.7	8.7				yes	GF = 1.017	[84]
	UV-LED 265 nm	0.7	1.3	6			yes	GF = 0.941	[84]
Aspergillus niger									
ATCC 32625	LP	116	245	370	560		yes		[85]
ATCC 32625	Excilamp 222 nm	62	150	222	294		yes	GF = 0.683	[85]
IFM 63883	Excilamp 222 nm	45	137				no	GF = 0.683	[86]
IFM 63883	LP	47	94				no		[86]
	LP		100				no		[87]
	UV-LED 265 nm	39	57	80			yes	GF = 0.941	[88]
	UV-LED 280 nm	18	29	39			yes		[88]
	LP	65	85				yes		[88]
	UV-LED 265 nm	31	53	70			yes	GF = 0.941	[89]
	UV-LED 280 nm	15	19	31	72		yes	GF = 0.486	[89]
	LP	60	85	167			yes		[89]
Aspergillus terreus									
	UV-LED 255 nm	2	4.3	7	16		yes	GF = 1.017	[84]
	UV-LED 265 nm	0.6	1.0	1.4	4		yes	GF = 0.941	[84]
Bacillus anthracis									
Sterne	LP	28	37	52			yes		[90]
Sterne	LP	23	30				yes		[14]
Ames	LP	25	~40	>120 with tailing			yes		[91]
34F2 (Sterne) method: soil extract–peptone–beef extract agar	LP	23	~40	>120 with tailing			yes		[91]

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation							
Spore	Lamp Type	1	2	3	4	5	Protocol?	Notes	Reference
34F2 (Sterne) method: Schaeffer's sporulation medium	LP	23	36	80			yes		[91]
Bacillus atrophaeus									
ATCC 9372	LP	22	38	55	71		yes		[92]
	LP	10	16	26	39		yes		[15]
	UV-LED 260 nm	6.2	10	14	20	32	yes	GF = 1.026	[15]
Bacillus cereus									
ATCC 11778	Excilamp 222 nm	17	29	47			yes	GF = 0.683	[85]
ATCC 11778	LP	52	93	140			yes		[85]
Endospores	Excilamp 222 nm	7.6	18	35			no	GF = 0.683	[86]
Endospores	LP	30	89				no		[86]
T	LP	23	30	35	40		yes		[14]
Vegetative cells	Excilamp 222 nm	5.2					no	GF = 0.683	[86]
Vegetative cells	LP	6.9	22				no		[86]
Bacillus megaterium (spores) QMB 1551	265 nm	*26*	*40*	*52*			no	GF = 0.941	[93]
Bacillus pumilus									
ASFUVRC	Filtered MP 258 nm	108	161	228			yes	GF = 1.240	[79]
ASFUVRC	LP	173	348				yes	(a)	[94]
ATCC 27142	LP	68	138	204	272		yes	(a)	[94]
ATCC 27142	LP	87	189				yes		[16]
ATCC 27142	MP	34	101	165			yes		[16]
ATCC 27142	UV-LED 260 nm	100	199	315			yes	GF = 1.389	[16]
ATCC 27142	UV-LED 280 nm	61	168				yes	GF = 0.953	[16]
ATCC 27142	LP	5.1	10	14	17	22	no		[95]
Bacillus subtilis									
ATCC 6633	LP	12	18	24	30	36	yes		[96]
ATCC 6633	LP	36	48	59	77		yes		[97]
ATCC 6633	LP	28	40	50			yes		[21]
ATCC 6633	LP	19	40	60	81		yes		[98]
ATCC 6633	LP	31	47	64	80		yes	Action spectrum	[99]
ATCC 6633	LP	25	39	50	60		yes		[90]
ATCC 6633	LP	24	35	47	79		yes		[100]

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation							
Spore	Lamp Type	1	2	3	4	5	Protocol?	Notes	Reference
ATCC 6633 (surface cultured)	LP	11	18	24	31		yes	Action spectrum	[101]
ATCC 6633 (liquid cultured)	LP	13	23	33			yes		[102]
ATCC 6633 (surface cultured)	LP	9	15				yes		[102]
ATCC 6633	LP	21	37	54				Medium: air – RH: 50-60%	[103]
ATCC 6633	LP	18	31	44				Medium: air – RH = 70-83%	[103]
ATCC 6633 (surface cultured)	Excilamp 222 nm	18	31	46	59		yes	GF = 2.570	[104]
ATCC 6633 (surface cultured)	LP	19	24	30	35		yes		[104]
ATCC 6633 (surface cultured)	282 nm	14	22	29	37		yes	GF = 0.748	[104]
ATCC 6633	LP	9	17	26	34		yes		[32]
ATCC 6633	LP	21	32	43	55		yes	Action spectrum	[37]
ATCC 6633 (surface cultured)	LP	18	39	61	82		yes		[105]
ATCC 6633	LP	24	37	51	80 + tailing		yes		[106]
ATCC 6633	LP	26	40	55	69		yes		[107]
ATCC 6633	Excilamp 222 nm	33	54	77	98		yes	GF = 2.570	[107]
ATCC 6633	Excilamp 172 nm	435	869				yes		[107]
ATCC 6633	UV-LED 269 nm	*3.2*	*16*	*27*	*39*		yes	GF = 1.576	[108]

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation							
Spore	Lamp Type	1	2	3	4	5	Protocol?	Notes	Reference
ATCC 6633	UV-LED 282 nm	*2.2*	*8.2*	*14*	*19*		yes	GF = 0.748	[108]
ATCC 6633	UV-LED 265 nm	54	115	172			yes	GF = 1.409	[109]
ATCC 6633	UV-LED 280 nm	48	107				yes	GF = 0.899	[109]
ATCC 6633	LP	23	33	43	50	68	yes	Action spectrum	[27]
ATCC 6633	UV-LED 265 nm	15	23	30	38	59	yes	GF = 1.409	[27, 110]
ATCC 6633	UV-LED 280 nm	16	25	31	43		yes	GF = 0.899	[27, 110]
ATCC 6633	UV-LED 300 nm	31	41	51	56		yes	GF = 0.047	[27, 110]
ATCC 6633	LP	9					no		[111]
ATCC 6633	LP	22	36	49	62	75	yes		[17]
ATCC 6051	LP	8	13	17	20 + tailing		yes		[112]
TKJ 6312	LP	0.7	1.5	2.3	3.7		yes		[98]
WN624	LP	25	36	49	60		yes		[90]
Cylindrospermum spores	LP	*14*	*26*	*43*			no		[113]
Clostridium pasteurianum									
ATCC 6013	LP	3.4	5.3	6.7	8.4		yes		[85]
ATCC 6013	Excilamp 222 nm	11	16	20	25		yes	GF = 2.570	[85]
Clostridium sporogenes									
JCM 1416 (endospores)	Excilamp 222 nm	2.9	5.9	14	48		no	GF = 0.683	[86]
JCM 1416 (endospores)	LP	5.2	11	63	95		no		[86]
JCM 1416 (vegetative cells)	Excilamp 222 nm	1.8	3.7				no	GF = 0.683	[86]
JCM 1416 (vegetative cells)	LP	4.1	14	28			no		[86]
Encephalitozoon intestinalis									
	LP	2.8	5.6	8.4			yes		[18]
(microsporidia)	LP & MP	*<3*	*3*	*<6*			yes		[114]
Fischeralla muscicola spores	LP	*189*					no		[113]
Penicillium expansum									
ATCC 36200	LP	11	38	49	65		yes		[85]
ATCC 36200	Excilamp 222 nm	15	23	29			yes	GF = 0.683	[85]
Streptomyces griseus									

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation							
Spore	Lamp Type	1	2	3	4	5	Protocol?	Notes	Reference
ATCC 10137	LP	8.5	13	15	18		yes		[85]
ATCC 10137	Excilamp 222 nm	8.9	12	14	18		yes	GF = 0.683	[85]
Thermoactinomyces vulgaris									
ATCC 43649	LP	55	90	115	140		yes		[85]
ATCC 43649	Excilamp 222 nm	17	26	31	38		yes	GF = 0.683	[85]

[a]The water depth was only 2 mm, so the water factor would have been very close to 1.0. Thus, although the protocol corrections were not made, the corrections would have been small

Table A2. Fluences for multiple log reductions for various bacteria.

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Bacterium	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
Actinobacter baumannii										
NCTC 12156	LP	0.6	1.8	3.3	4.8			yes		[19]
Aeromonas hydrophila										
ATCC7966	LP	1.1	2.5	4.0	5.5	6.9	8.4	yes		[115]
Aeromonas salmonicida										
AL 2017	LP	1.5	2.7	3.1	5.9			yes		[116]
Arthrobacter nicotinovorans										
ATCC 49919	LP	8	10	12	14			yes		[85]
ATCC 49919	Excilamp 222 nm	6.8	10	12	14			yes	GF = 0.683)	[85]
***Bacillus cereus* (veg. bacteria)**										
ATCC 11778	LP	6	7	9	12			yes		[85]
ATCC 11778	Excilamp 222 nm	6.1	7.5	9.6	12			yes	GF = 0.683	[85]
Bacillus megaterium										
(veg. cells) QMB 1551	265 nm	*4.3*						no	GF = 0.941	[93]
Burkholderia mallei										
M9	LP	1.0	2.4	3.8	5.2			yes		[91]
M13	LP	1.2	2.7	4.1	5.5			yes		[91]
Brucella melitensis										
ATCC 23456	LP	2.8	5.3	7.8	10			yes		[91]
IL195	LP	3.7	5.8	7.8	9.9			yes		[91]
Burkholderia pseudomallei										
ATCC 11688	LP	1.7	3.5	5.5	7.4			yes		[91]
CA650	LP	1.4	2.8	4.3	5.7			yes		[91]

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Bacterium	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
Brucella suis										
KS528	LP	2.7	5.3	7.9	11			yes		[91]
MO 562	LP	1.7	3.6	5.6	7.5			yes		[91]
Campylobacter jejuni										
ATCC 43429	LP	1.0	2.1	3.4	4.6	5.8		yes		[115]
Biotype 1 strain 709/84	LP	0.8	1.3	1.7	2.1			yes		[117]
Citrobacter diversus	LP	5	7	9	11	13		yes		[20]
Citrobacter freundii	LP	5	9	13				yes		[20]
Clostridioides difficile										
JCM 1296 (endospores)	Excilamp 222 nm	3.6	7.9	17				no	GF = 0.683	[86]
JCM 1296 (endospores)	LP	11	23					no		[86]
Corynebacterium diphtheriae	LP	*3.4*						no		[118]
Deinococcus radiodurans										
ATCC 13939	LP	113	142	170	205			yes		[85]
ATCC 13939	Excilamp 222 nm	30	39	62				yes	GF = 0.683	[85]
Eberthella typhosa	LP	*2.1*						no		[118]
Enterococcus faecium										
Vancomycin-resistant	LP	7	9	11	13	15		yes		[119]
Enterococcus faecalis										
ATCC 27285	LP	3.7	8.0	14 + tailing				yes		[120]
ATCC 27285	LP	3.4	9.1	18				yes		[121]
ATCC 27285	LP	3.4	11	15				yes		[122]
DSM 13590	LP	60 mJ cm^{-2} for 0.7 log reduction						yes		[123]
DSM 20478	LP	7.1	8.7	13 + tailing				yes		[124]
DSM 20478	MP	5.5	7.6	12 + tailing				yes		[124]
MH773161.1	LP	3.3	6.9	12	16	23		yes		[125]
Escherichia coli										
ATCC 11229	LP	3.0	4.8	6.7	8.4	11		yes		[97]
ATCC 11229	LP	2.5	3.0	3.5	5	10	15	yes		[126]
ATCC 11229	LP	*7*	*8*	*9*	*11*	*12*		no		[22]
ATCC 11229	LP	3.4	5.0	6.7	8.3	10		yes		[21]
ATCC 11229	LP	3.5	4.7	5.5	6.5	7.5	9.6	yes		[23]
ATCC 11229	LP	2.5	3.0	3.5	4.5	5.0	6.0	yes		[24]
ATCC 11229	LP	3.9	5.4	6.8	8.2	9.7		yes		[127]
ATCC 11229	LP	3.3	4.9	5.7	6.6			yes		[128]
ATCC 11229	Excilamp 222 nm	3.3	5.3	6.2	7			yes	GF = 0.683	[128]

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Bacterium	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
ATCC 11229	LP or MP	1.6	3.0	5	6.5			yes		[81]
ATCC 11229	LP	4.7	6.2	7.2	8.3	9.3		yes		[129]
ATCC 11229	MP	2.5	4	4.7	5.3	6.0	7.3	yes		[129]
ATCC 11229	LP	4.1	5.1	6.2				yes		[130]
ATCC 11229	UV-LED 255 nm	*6.3*	*8.4*					yes	GF = 1.063	[130]
ATCC 11229	UV-LED 275 nm	4.5	6.4	8				yes	GF = 1.038	[130]
ATCC 11229	UV-LED 265 nm	3.9	5.6					yes	GF = 1.345	[131]
ATCC 11229	UV-LED 265 nm	4.3	5.8	7.1	8.3	9.4		yes	GF = 1.345	[132]
ATCC 11229	Microplasma UV 221 nm	2.8	4.3	5.8	7.4			yes	GF = 0.736	[133]
ATCC 11303	LP	4	6	9	10	13	15	yes		[134]
ATCC 11775	LP	1.1	2.0	3.0	3.4	4.0		yes		[129]
ATCC 11775	MP	0.9	1.6	2.4	3.0	3.4		yes		[129]
ATCC 15597	LP	6.4	8.9	11	12	13		yes		[129]
ATCC 15597	MP	5.0	6.8	8.3	9.4	11	12	yes		[129]
ATCC 15597	MP 297 nm	0.5	0.7	0.9	1.1	1.4		yes	GF = 0.019	[135]
ATCC 15597	MP 310 nm	191	320	360	401	442		yes		[135]
ATCC 25922	LP	6.0	6.5	7.0	8.0	9	10	yes		[21]
ATCC 25922 – Antibiotic sensitive	LP	2	4	5.7	7.5	29		yes		[136]
ATCC 25922	LP	2.1	3.9	5.9	8	11		yes		[137]
ATCC 29425	LP	5.4	8.5	20				yes		[25]
ATCC 29425	UV-LED 265 nm	4.8	7.9	23	27			yes	GF = 1.345	[25]
ATCC 700891	LP	7.3	10	12	13	15		yes		[129]
ATCC 700891	MP	4.8	6.8	8.2	9.0	9.8		yes		[129]
ATCC 8739	LP	9.4	12	14	19			yes		[138]
ATCC 8739	UV-LED 275 nm	6.4	11	14	17	20		yes	GF = 1.038	[138]
B	LP	1.0	2.4	4.4	6			yes		[139]
B	MP	0.9	2.1	4.2	6			yes		[139]
B ATCC 13033	LP	1.2	3.0	4.7	6.5	8.2	10	yes		[15]
B ATCC 13033	UV-LED 260 nm	1.5	3.8	5.9	8.2	10	13	yes	GF = 1.259	[15]
C	LP	2	3	4	5.6	6.5	8	yes		[140]

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Bacterium	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
C3000	LP or MP	3.0	4.3	5.5	7.0			yes		[141]
CGMCC 1.1595	LP	3.1	17	25	31	36		yes		[142]
CGMCC 1.2154	LP	4	8	12	16	19		yes		[143]
CGMCC 1.2154	MP	2.6	5.1	7.7	11	19		yes		[143]
CGMCC 1.3373	LP	3.1	5.9	8.0	13			yes		[26]
CGMCC 1.3373	MP	3.1	5.9	9.6	13			yes		[26]
CGMCC 1.3373	LP	4.8	6.7	8.7	12	15		yes		[144]
CGMCC 1.3373	UV-LED 265 nm	3.5	6.3	8.3	11	15		yes	GF = 1.345	[144]
CGMCC 1.3373	UV-LED 280 nm	3.9	5.7	7	8.8	13		yes	GF = 0.709	[144]
CGMCC 1.3373	UV-LED 267 nm	5.5	8.3	11	15			yes	GF = 1.337	[145]
CGMCC 1.3373	UV-LED 275 nm	5.6	9.3	13				yes	GF = 1.038	[145]
CN13	XeBr Exci-lamp 282 nm	3.1	4.2	5.4	6.8				GF = 0.564	[146]
DSM 4960	LP	60 mJ cm^{-2} for 0.7 log reduction						yes		[123]
DSM 787	UV-LED 265 nm	1.5	3.1	3.9	4.7	5.5		no	Droplets – GF = 1.345	[147]
EHEC	Excilamp 222 nm	1.6	3.1	4.8	6.9			no	GF = 0.683	[86]
K12	LP	*1.1*	*1.9*	*2.6*	*3.4*			no		[148]
K12 ATCC 29425	LP	3.7	8.6	11				yes		[16]
K12 ATCC 29425	MP	5	7.2	11				yes		[16]
K12 ATCC 29425	UV-LED 260 nm	5.5	8.7	13				yes	GF = 1.259	[16]
K12 ATCC 29425	UV-LED 280 nm	3.3	4.8	6.6	9.1			yes	GF = 0.709	[16]
K12 ATCC 29425	LP	4.2	6	7.7	14			yes	Action spectrum	[28]
K12 ATCC 29425	UV-LED 255 nm	3.6	5.3	6.5	9			yes	GF = 1.063	[28]
K12 ATCC 29425	UV-LED 265 nm	3.2	6.1	7.8	9.4	11		yes	GF = 1.345	[28]
K12 ATCC 29425	UV-LED 285 nm	1.9	3.4	4.2	5			yes	GF = 0.355	[28]
K12 ATCC 29425	LP	4.1	8.2	12	16	33		yes		[149]
K12 IFO 3301	LP & MP	2	4	6	7	9		yes		[150]
K12 IFO 3301	LP	1.5	2.0	3.5	4.2	5.5	6.2	yes		[140]

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Bacterium	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
K12 IFO 3301	LP & MP	2.2	4.4	6.7	8.9	11		yes		[34]
K12 IFO 3301	UV-LED 265 nm	3.5	6.3	8.9	12	16		yes	GF = 1.345	[80]
K12 IFO 3301	UV-LED 280nm	2.4	4.9	7.1	9.9			yes	GF = 0.709	[80]
K12 IFO 3301	LP	1.9	4	6	8			yes		[29]
K12 IFO 3301	UV-LED 285 nm	2.8	4.6	5.7	8.2	12		yes	GF = 0.355	[151]
K12 IFO 3301	LP	2	4	6				yes		[30]
K12 IFO 3301	UV-LED 280 nm	4.5	9.7	10	17	24		yes	GF = 0.709	[151]
IFO 3301	LP	3.7	5.5	6.7	7.3	9.7		yes		[27]
IFO 3301	UV-LED 265 nm	3.5	5.1	6.7	8.2	14		yes	GF = 1.345	[27, 110]
IFO 3301	UV-LED 280 nm	2.6	4	4.9	6.4			yes	GF = 0.709	[27, 110]
IFO 3301	UV-LED 300 nm	1.4	1.9	2.3	2.8			yes	GF = 0.032	[27, 110]
INR6 – Antibiotic resistant	LP	5	6.7	8.6	11	19		yes		[136]
INR8 – Antibiotic resistant	LP	4.3	5.4	6.5	7.7	14		yes		[136]
NBIMB 9481	LP	5.9	8.0	9.3	11	12		yes		[129]
NBIMB 9481	MP	4.3	6.2	7.3	8.6			yes		[129]
NBIMB 10083	LP	2.8	4.4	5.6	6.6	7.6		yes		[129]
NBIMB 10083	MP	2.5	4.3	5.1	6.0	6.8	7.6	yes		[129]
NCTC 12241 – Antibiotic sensitive	LP	0.9	3.3	4.3	5.4	6.4		yes		[31]
NCTC 13400 – Antibiotic resistant	LP	0.4	0.8	1.3	1.9	2.6		yes		[31]
OP50	LP	2.0	4.4	6.7	9.1			yes		[32]
O157: H7	LP	*1.5*	*3.0*	*4.5*	*6.0*			no		[152]
O157: H7	LP	*<2*	*<2*	*2.5*	*4*	*8*	*17*	??		[153]
O157: H7 ATCC 43894	LP	1.4	2.8	4.2	5.5	6.9		yes		[115]
O157: H7 ATCC 35150, ATCC 43889, ATCC 43890	KrCl excilamp 222 nm	0.2	0.4	0.7				no	Initial population: 10^{4-5} CFU[a]/mL; GF = 0.683	[154]
O157: H7 ATCC 35150, ATCC 43889, ATCC 43890	KrCl excilamp 222 nm	0.4	0.6	0.8				no	Initial population: 10^{5-6} CFU/mL; GF = 0.683	[154]

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Bacterium	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
O157: H7 ATCC 35150, ATCC 43889, ATCC 43890	KrCl excilamp 222 nm	0.5	1					no	Initial population: 10^{6-7} CFU/mL; GF = 0.683	[154]
O157: H7 ATCC 35150, ATCC 43889, ATCC 43890	LP	0.2	0.5	0.7	0.9	1.6		yes	(b)	[155]
O157: H7 ATCC 35150, ATCC 43889, ATCC 43890	KrCl excilamp 222 nm	0.1	0.3	0.5	0.6	1.1		yes	(b) GF = 0.683	[155]
O157: H7 CCUG 29193	LP	3.5	4.7	5.5	7			yes		[23]
O157: H7 CCUG 29197	LP	2.5	3.0	4.6	5.0	5.5		yes		[23]
O157: H7 CCUG 29199	LP	0.4	0.7	1.0	1.1	1.3	1.4	yes		[23]
O25: K98: NM	LP	5.0	7.5	9	10	12		yes		[23]
O26	LP	*5.4*	*8.0*	*11*	*13*			no		[152]
O50: H7	LP	2.5	3.0	3.5	4.5	5	6	yes		[23]
O78: H11	LP	4	5	5.5	6	7		yes		[23]
145 Ampicillin resistant	LP	0.8	1.9	3.0	4.7			yes		[19]
018 Trimethoprim resistant	LP	1.5	3.0	4.0	4.9			yes		[19]
SER2 – Antibiotic resistant	LP	1.7	3.4	5.5	7.8	28		yes		[136]
SER6-1 – Antibiotic resistant	LP	6	8.8	11	13	18		yes		[136]
SER6-2 – Antibiotic resistant	LP	5.2	6.9	8.8	11	24		yes		[136]
SMS-3-5	LP	3	5.1	6.5	7.6			yes		[119]
Wild type	LP	2.7	4.0	5.3	6.6			yes		[117]
Wild type	LP	4.4	6.2	7.3	8.1	9.2		yes		[23]
	LP	2.0	3.6	5.2	6.8			yes		[156]
	LP		20					no		[87]
	UV-LED 265 nm	5.6	8.7	13				yes	GF = 1.345	[157]
	UV-LED 285 nm	4						yes	GF = 0.355	[157]
Fecal coliforms	LP	6	9	13	22			yes		[158]
Francisella tularensis										
LVS	LP	1.3	3.1	4.8	6.6			yes		[91]
NY98	LP	1.4	3.8	6.3	8.7			yes		[91]
Fecal streptococci	LP	9	14	22	30			yes		[158]
Halobacterium elongata										
ATCC 33173	LP	*0.4*	*0.7*	*1.0*				no		[159]
Halobacterium salibarum										

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Bacterium	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
ATCC 43214	LP	*12*	*15*	*18*	*20*			no		[159]
Helicobacter pylori										
Texas isolate	LP	2.2	3.0	3.8	4.6	5.7	6.6	yes		[160]
ATCC 43504	LP	4.5	5.7	6.7	7.5	8.0		yes		[160]
ATCC 49503	LP	1.7	3.1	4.0	5.3	7		yes		[160]
Klebsiella pneumoniae	LP	5	7	10	12			yes		[20]
Klebsiella terrigena										
ATCC 33257	LP	3.6	6.4	9.3	12	15		yes		[115]
Kocuria rhizophila										
DSM 11926	LP	7.1	14	25				yes		[161]
Legionella longbeachae										
ATCC 33462	LP	1.4	3.0	4.7	6.3			yes		[33]
Legionella pneumophila										
Philadelphia 2	LP	*0.9*	*1.8*	*2.8*	*3.7*			no		[162]
ATCC 33152	LP	1.6	3.2	4.8	6.4	8.0		yes		[34]
ATCC 33152	MP	1.9	3.8	5.8	7.7	9.6		yes		[34]
ATCC 33152	LP	1.7	3.0	4.3	5.7			yes		[33]
ATCC 33152	LP	1.9	3.4	4.8	5.8			yes		[27]
ATCC 33152	UV-LED 265 nm	1.9	3.2	4.7	6.3			yes	GF = 1.474	[27, 110]
ATCC 33152	UV-LED 280 nm	1.7	2.9	4.8	6.4			yes	GF = 0.730	[27, 110]
ATCC 33152	UV-LED 300 nm	2	3.1	4.6	6.5			yes	GF = 0.074	[27, 110]
ATCC 33823	LP	1.7	3.1	4.5	5.8			yes		[33]
ATCC 43660	LP	3.0	5.0	7.2	9.3			yes		[115]
Sero group 1	LP	1.7	2.9	4.2	5.4			yes		[33]
Sero group 8	LP	1.8	3.3	4.7	6.1			yes		[33]
Leptospira										
biflexa serovar patoc Patoc I	LP	2.3	3.8	5.1	6.7			no		[163]
illini 3055	LP	2.8	3.8	4.8				no		[163]
interrogans serovar Pomona Pomona	LP	0.8	1.2	1.7				no		[163]
Listeria monocytogenes										
	LP	*2.2*	*3.0*	*3.2*	*4.1*	*4.6*		no		[164]
ATCC 19111, ATCC 19115, ATCC 15313	KrCl excilamp 222 nm	0.3						no	Initial population: 10^{4-5} CFU/mL;	[154]

Bacterium	Lamp Type	Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation						Protocol?	Notes	Reference
		1	2	3	4	5	6			
									GF = 0.683	
ATCC 19111, ATCC 19115, ATCC 15313	KrCl excilamp 222 nm	0.5	0.8	1				no	Initial population: 10^{5-6} CFU/mL; GF = 0.683	[154]
ATCC 19111, ATCC 19115, ATCC 15313	KrCl excilamp 222 nm	0.8						no	Initial population: 10^{6-7} CFU/mL; GF = 0.683	[154]
ATCC 19111, ATCC 19115, ATCC 15313	LP	1.7	2.6	3.4	4.2	5		yes	(b)	[155]
ATCC 19111, ATCC 19115, ATCC 15313	KrCl excilamp 222 nm	0.6	1.2	1.6	2.1	2.6		yes	(b) GF = 0.683	[155]
Morganella morganii										
MH773160.1	LP	3.7	7.4	13	19	25		yes		[125]
Mycobacterium avium										
33B	LP	5.8	8.1	10	13			yes		[165]
W41	LP	5.7	7.9	10	12	15		yes		[165]
D55A01	LP	6.4	9.4	12	15			yes		[165]
Mycobacterium avium hominissuis										
HMC02 (white transparent) (WT)	LP	7.7	12	17	22			yes		[139]
HMC02 (white transparent) (WT)	MP	8.1	12	16				yes		[139]
HMC02 (white opaque) (WO)	LP	7.1	11	17				yes		[139]
HMC02 (white opaque) (WO)	MP	6.6	11	15	19			yes		[139]
Mycobacterium bovis BCG	LP	*2.2*	*4.4*					no		[164]
Mycobacterium intracellulare										
B12CC2	LP	7.8	11	13	16			yes		[165]
ATCC 13950	LP	7.4	11	15	19			yes		[165]
Mycobacterium phlei	LP	*3.6*						no		[164]
Mycobacterium terrae										
ATCC 15755	LP	3.9	9.3	16 + tailing				yes	(c)	[35]
ATCC 15755	LP	3.7	9.3	16				yes		[36]
ATCC 15755	MP	3.2	11	39				yes		[36]
Mycobacterium tuberculosis	LP	*2.2*	*4.3*					no		[164]

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Bacterium	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
Pseudomonas aeruginosa										
ATCC 9027	LP	*3.8*	*6.5*	*10*	*17*			no		[166]
ATCC 10145	LP	*4.6*						no		[166]
ATCC 10145	LP	2.8	5.5	7	9.3			yes		[27]
ATCC 10145	UV-LED 265 nm	3.3	5.1	6.8	8.4			yes	GF = 1.338	[27, 110]
ATCC 10145	UV-LED 280 nm	3.7	5	7.5	10			yes	GF = 1.090	[27, 110]
ATCC 10145	UV-LED 300 nm	3.9	5.4	6.9	8.3			yes	GF = 0.095	[27, 110]
ATCC 14207	LP	*3.7*						no		[166]
ATCC 15442	LP	*3.8*						no		[166]
ATCC 15442	LP	1.6	3	4.8	8			yes		[28]
ATCC 15442	UV-LED 255 nm	1.7	3.3	4.2	5.3	7.7		yes	GF = 1.320	[28]
ATCC 15442	UV-LED 265 nm	1.4	2.8	4.2	5.5			yes	GF = 1.108	[28]
ATCC 15442	UV-LED 285 nm	2	3.7	5	7			yes	GF = 0.823	[28]
ATCC 27853	LP	*4.9*						no		[166]
ATCC 27853	LP	0.8	1.6	2.3	3.1			yes		[85]
ATCC 27853	Excilamp 222 nm	2.1	3.3	4	5.1	6.8		yes	GF = 0.683	[85]
01	LP	1.3	2.7	4.3	6.3	10		yes		[119]
B2	LP	*5.6*						no		[166]
G2	LP	*3.0*						no		[166]
BS4	LP	*3.5*						no		[166]
NCTC 13437 – Antibiotic resistant	LP	0.7	1.5	2.3	6			yes		[31]
WB1	LP	*5.8*						no		[166]
SH-2918	LP	*3.5*						no		[166]
	Excilamp 222 nm	1.3	2.6	3.9	6.2			no	GF = 0.683	[86]
Pseudomonas litoralis										
CECT 7670T	LP	5.3	13					yes		[161]
Pseudomonas luteola										
Trimethoprim resistant HPC	LP	1.2	2.8	4.6	6.7			yes		[31]
Pseudomonas putida										
CP1 planktonic cells	LP	0.7	2.7	3.5	13			no		[167]
CP1 aggregated cells	LP	206	412	618	825	1031		no		[167]
***Roseobacter* sp.**										
CECT 7117	LP	4.2	6.4	10	18			yes		[161]

Bacterium	Lamp Type	Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation						Protocol?	Notes	Reference
		1	2	3	4	5	6			
***Salmonella* spp.**	LP	*<2*	*2*	*3.5*	*7*	*14*	*29*	??		[153]
Salmonella typhimurium										
ATCC 6539	LP	2.6	4.5	5.8	7	8		yes		[97]
ATCC 19430	LP	2.0	4.1	6.2	8.3			yes		[115]
ATCC 19585, ATCC 43971, DT 104	KrCl excilamp 222 nm	0.5	1.2	1.8				no	Initial population: 10^{4-5} CFU/mL; GF = 1.360	[154]
ATCC 19585, ATCC 43971, DT 104	KrCl excilamp 222 nm	0.8	1.5	2	2.4			no	Initial population: 10^{5-6} CFU/mL; GF = 1.360	[154]
ATCC 19585, ATCC 43971, DT 104	KrCl excilamp 222 nm	1.1	2.3					no	Initial population: 10^{6-7} CFU/mL; GF = 1.360	[154]
ATCC 19585, ATCC 43971, DT 104	LP	0.6	1.5	2.6	3.2	3.7		yes	(b)	[155]
ATCC 19585, ATCC 43971, DT 104	KrCl excilamp 222 nm	0.7	1.4	2.3	3.3	3.9		yes	(b) GF = 1.360	[155]
(in act. sluge)	LP	3	12	22	50			yes		[158]
LT2	LP	3.4	4.6	5.7	7.3			yes	Action spectrum	[38]
LT2	XeBr excilamp 282 nm	2.4	4.1	5.4	6.5			yes	GF = 0.646	[38]
LT2	MP 289 nm	2	5.8	6.7	7.8			yes	GF = 0.386	[38]
LT2	MP 297 nm	3.5	5.8	8.2	11			yes	GF = 0.162	[38]
LT2	MP 310 nm	1.5	4.5	5.7				yes	GF = 0.015	[38]
LT2	MP 320 nm	1.9						yes	GF = 0.018	[38]
LT2	MP 330 nm	1.9	4.2					yes	GF = 0.014	[38]
LT2 SL3770	LP	4	5.7	7.8				yes	Action spectrum	[37]
Salmonella enterica subsp. *enterica* serovar Typhimurium	Excilamp 222 nm	5	11	17	25			no	GF = 1.360	[86]
Salmonella enterica subsp. *enterica* serovar Typhimurium	LP	2.3	4.6	8.9				no		[86]
	LP	3.9	5.3	6.7	7.7	13		yes		[156]
Serratia marcescens	LP	*2.2*						no		[118]
Shewanella algae	LP	*0.9*	*1.7*	*2.4*	*3.2*			no		[148]

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Bacterium	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
Shewanella oneidensis										
DLM7	LP	*0.3*	*0.5*	*0.8*	*1.1*			no		[148]
MR4	LP	*0.7*	*1.4*	*2.1*	*2.8*			no		[148]
MR1	LP	*0.2*	*0.4*	*0.6*	*0.9*			no		[148]
Shewanella putrefaciens 200	LP	*0.5*	*0.8*	*1.1*	*1.4*			no		[148]
Shigella dysenteriae										
ATCC 29027	LP	0.1	1.0	1.9	2.8	3.8	4.7	yes		[115]
	LP	0.5	1.1	1.9	2.5	3.1		yes		[156]
Shigella paradysenteriae	LP	*1.7*						no		[118]
Shigella sonnei										
ATCC 9290	LP	3.2	4.9	6.5	8.2			yes		[97]
Staphylococcus albus										
	LP	*1.8*						no		[118]
	LP	*1.1*	*3.2*	*4.0*	*4.8*			no		[164]
Staphylococcus aureus										
	LP	2.1	3.2					no	Action spectrum	[39]
(hem)	LP	*2.6*						no		[118]
ATCC 25923	LP	3.9	5.4	6.5	10			yes		[97]
ATCC 25923	LP	4.4	5.8	6.4	7.3	9		yes		[85]
ATCC 25923	Excilamp 222 nm	9	12	14	17			yes	GF = 0.9625	[85]
ATCC 27649, ATCC 25923, ATCC 27213	LP	1.7	2.6	3.4	4.2	5.2		yes	(b)	[155]
ATCC 27649, ATCC 25923, ATCC 27213	KrCl excilamp 222 nm	1.3	1.9	2.4	2.8	3.7		yes	(b) GF = 0.9625	[155]
ATCC BAA-1556 (Methicillin resistant)	LP	4.5	7.2	8.8	10			yes		[119]
CGMCC 1.2465	LP	2.7	5.4	8.2	12	18		yes		[143]
CGMCC 1.2465	MP	3.7	7.3	12	18	34		yes		[143]
MRSA – Meticillin resistant	Excilamp 222 nm	1.3	2.4	3.7	4.9			no	GF = 0.9625	[86]
MRSA – Meticillin resistant	LP	1.2	2.4	3.7	4.8			no		[86]
Streptococcus faecalis ATCC 29212	LP	6.6	8.6	9.8	11			yes		[97]
Streptococcus hemolyticus	LP	*2.2*						no		[118]
Vibrio anguillarum	LP	0.5	1.2	1.5	2.0			yes		[116]
Vibrio cholerae										
Classical OGAWA 154	LP	*0.8*	1.4	2.3	3.9	6.8		no		[168]

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Bacterium	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
el tor MAK 154	LP	*1.7*	4.1	7.1				no		[168]
NAG 1976	LP	*2.5*	8.9					no		[168]
ATCC 25872	LP	0.7	1.4	2.1	2.8	3.6		yes		[115]
Vibrio harveyi										
	LP	5.2	6.9	8.9				yes		[38]
	XeBr excilamp 282 nm	4.7	6.8	9.4				yes	GF = 0.786	[38]
	MP 289 nm	3.2	7	9.7				yes	GF = 0.342	[38]
	MP 297 nm	4.6	7.3	9.3				yes	GF = 0.103	[38]
	MP 310 nm	3.7	5.7	9.5				yes	GF = 0.013	[38]
	MP 320 nm	3						yes	GF = 0.025	[38]
	MP 330 nm	3.8	7.1					yes	GF = 0.005	[38]
Vibrio parahaemolyticus										
2977	LP	*4.4*						no		[168]
NBRC 12711	UV-LED 265 nm	2.8	5.4	8	10.6			yes	GF = 0.941	[110]
NBRC 12711	UV-LED 280 nm	2.3	4	5.7	7.4			yes	GF = 0.486	[110]
NBRC 12711	UV-LED 300 nm	2	4.2	6.4	8.6			yes	GF = 0.037	[110]
Yersinia enterocolitica										
Sero-group 0:3 strain 304/84	LP	1.2	2.2	3.0	3.6			yes		[117]
ATCC 4780	LP	2.1	4.1	5.0	5.8			yes		[128]
ATCC 4780	Excilamp 222 nm	2.1	4.2	5.2	6	6.8	8.2	yes	GF = 0.683	[128]
ATCC 27729	LP	1.6	2.7	4.0	5.1			yes		[115]
Yersinia pestis										
A1122	LP	1.4	2.6	3.7	4.9			yes		[91]
Harbin	LP	1.3	2.2	3.2	4.1			yes		[91]
Yersinia ruckeri	LP	1	2	3	4			yes		[116]

[a]Colony Forming Unit
[b]The water depth was only 2 mm, so the water factor would have been very close to 1.0. Thus, although the protocol corrections were not made, the corrections would have been small
[c]Spiked into wastewater

Table A3. Fluences for multiple log reductions for various protozoa.

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation							
Protozoan	Lamp Type	1	2	3	4	5	Protocol?	Notes	Reference
Acanthamoeba castellanii									
ATCC 30234 (life stage: trophozoites, plaque assay)	LP	40					yes		[97]
CCAP 15342 (life stage: trophozoites, method: MPN[a])	LP	32	52	72			yes		[33]
CCAP 15342 (life stage: cysts, method: MPN)	LP	45	75	91	125		yes		[33]
Acanthamoeba culbertsoni ATCC 30171 (mouse infectivity assay, *Mus musculus* species, strain CD-1)	LP	38	58	125	148		yes		[158]
***Acanthamoeba* spp.**									
isolated strain (life stage: trophozoites, mouse infectivity assay, *Mus musculus* species, strain CD-1)	LP	39	75	132	160		yes		[158]
155 (life stage: trophozoites, method: MPN)	LP	28	31	66	71		yes		[33]
155 (life stage: cysts, method: MPN)	LP	34	67	99			yes		[33]
Cryptosporidium hominis [cell culture infectivity assay using HCT-8 cells (CCL-244) & MDBK cells]	LP & MP	3.0	5.8				yes		[40]
Cryptosporidium parvum									
[mouse infectivity assay (neonatal CD-1 mice)]	MP	<3	<3	<3	19		yes		[169, 170]
[mouse infectivity assay (neonatal CD-1 mice)]	LP	<3	<3	3-6	>16		yes		[41]
[mouse infectivity assay (neonatal CD-1 mice)]	MP	<3	<3	3-9	>11		yes		[41]
[mouse infectivity assay	LP & MP								

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation							
Protozoan	Lamp Type	1	2	3	4	5	Protocol?	Notes	Reference
(neonatal CD-1 mice)]		2.4	<5	5.2	9.5		yes		[47]
[mouse infectivity assay & cell culture infectivity assay using MDCK cells (CCL-34)]	LP	1	2	>5			yes		[42]
[mouse infectivity assay (neonatal CD-1 mice)]	MP	<10	<10	>10			yes		[171]
[mouse infectivity assay (SCID mice)]	LP	0.5	1.0	1.4	2.2		no		[43]
[cell culture infectivity assay using HCT-8 cells (CCL-244)]	LP	2	<3	<3			yes		[44]
[cell culture infectivity assay using HCT-8 cells (CCL-244)]	MP	<1	<1	<1			yes		[44]
[cell culture infectivity assay using HCT-8 cells (ATCC CCL-244)]	LP	1.9	2.6	3.6			yes		[38]
[cell culture infectivity assay using HCT-8 cells (ATCC CCL-244)]	XeBr excilamp 282 nm	1.4	2.2	3			yes	GF = 0.812	[38]
[cell culture infectivity assay using HCT-8 cells (ATCC CCL-244)]	MP 289 nm	2.4	3.4	4.9			yes	GF = 0.532	[38]
[cell culture infectivity assay using HCT-8 cells (ATCC CCL-244)]	MP 297 nm	2.5	4				yes	GF = 0.202	[38]
[cell culture infectivity assay using HCT-8 cells (ATCC CCL-244)]	MP 310 nm	1.5	2.3	3.9			yes	GF = 0.026	[38]
[cell culture infectivity assay using HCT-8 cells (ATCC CCL-244)]	MP 320 nm	1.9	2.6	3.7			yes	GF = 0.052	[38]
[cell culture infectivity assay using HCT-8 cells (ATCC CCL-244)]	MP 330 nm	1.8	2.4	3.5	5		yes	GF = 0.059	[38]
[culture-immunofluorescence (CC–IFA)–based infectivity assay]	MP	1	2	2.9	4		yes		[172]
[mouse infectivity assay (neonatal CD-1 mice)]	LP	<2	<2	<2	<4	<10	yes		[45]
[mouse infectivity assay (neonatal CD-1 mice)]	MP	<5	<5	<5	~6		yes		[50]
[cell culture infectivity assay using HCT-8 cells	LP	1.8	5.6	25			yes		[46]

Protozoan	Lamp Type	Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation					Protocol?	Notes	Reference
		1	2	3	4	5			
(CCL-244)]									
HNJ-1 [mouse infectivity assay (SCID mice)]	LP	<0.7	<1.4	2.2			yes		[30]
[cell culture infectivity assay using HCT-8 cells (CCL-244)]	Laser 254 nm	1.3	1.9	2.3	2.8		yes	Action spectrum	[79]
***Cryptosporidium* spp.**	LP & MP	0.8	1.5	3.0	6.0		yes	(b)	[10]
Giardia lamblia									
(excystation assay)	LP?	*40*	*180*				no?		[173]
(gerbil infectivity assay)	LP	<10	~10	20			yes		[174]
(gerbil infectivity assay)	LP	<0.5	<0.5	<0.5	<1		yes		[48]
(gerbil infectivity assay)	LP	<2	<2	<4			yes		[49]
Giardia muris									
(mouse infectivity assay)	MP	1	4.5	28 + tailing			yes		[175]
(mouse infectivity assay)	MP	<10	<10	<25	~60		yes		[171]
(mouse infectivity assay)	LP	<2	<2	<4			yes		[49]
(mouse infectivity assay)	LP	*<2*	*<2*	*~2*	*~2.3*		no		[51]
(mouse infectivity assay)	LP	<5	<5	5			yes		[50]
***Giardia* spp.**	LP & MP	0.6	1.1	1.9	3.4		yes	(b)	[10]
Naegleria fowleri									
Cysts (method: MPN)	LP	32	63	104	121		yes		[176]
Trophozoites (method: MPN)	LP	8	13	18	24		yes		[176]
Toxoplasma gondii									
Oocysts [immunofluorescence assay (IFA)]	LP	7.2	13	17	19		yes		[177]
[mouse infectivity assay (SCID mice)]	LP	3.4	6.8	10			yes		[178]
Vermamoeba vermiformis									
CCAP 15434 /7A (life stage: trophozoites, method: MPN)	LP	11	19	26	34		yes		[33]
CCAP 15434/7A (life stage: cysts, method: MPN)	LP	17	38	54	78		yes		[33]
195									

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation							
Protozoan	Lamp Type	1	2	3	4	5	Protocol?	Notes	Reference
(life stage: trophozoites, method: MPN)	LP	10	17	24	32		yes		[33]
195 (life stage: cysts, method: MPN)	LP	32	60	76	110		yes		[33]

[a]Most Probable Number
[b]These data are medians derived from a Bayesian analysis of many studies

Table A4. Fluences for multiple log reductions for various viruses

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
Adenovirus											
Type 1 method: MPN	PLC/PRF5 and HeLa cell line	LP	35	69	103	138			yes		[179]
Type 2	PLC/PRF5	LP	40	78	119	160	195	235	yes		[52]
Type 2	Human lung cell line	LP	35	55	75	100			yes		[58]
Type 2	A549 cell line	LP	20	45	80	110			yes		[59]
Type 2	A549 cell line	LP	~30	~60					yes		[60]
Type 2	A549 cell line	MP	~10	~20	~30	~40	~50		yes		[60]
Type 2	A549 cell line	MP <240 nm blocked	~15	~30	~45	~60			yes		[60]
Type 2	A549 cell line	LP	8	31	50	80	117		yes		[61]
Type 2 method: TCID50[a]	A549 cell line	LP	35	78	126	168			yes		[62]
Type 2 method: TCID50	A549 cell line	MP	14	29	44	80	120		yes	(b)	[62]
Type 2 method: cell culture	HEK293 cells human embryonic kidney	LP	37	88	120				yes		[63]
Type 2	A-549										

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
adenoid 6 (VR-846)	cell line (CCL-185)	LP	42	83	124	166			yes		[64]
Type 2	A549 cell line	MP	4	7	14	22	40 + tailing		yes		[61]
Type 2 method: TCID50	A549 cell line (CCL-185)	LP	36	82					yes		[65]
Type 2 method: TCID50	A549 cell line (CCL-185)	MP	15	29	45	59	80		yes		[65]
Type 2 ATCC VR-846, method: TCID50	A549 cell line (CCL-185)	LP	56	108	159	206			yes		[53]
Type 2 method: plaque assay	A549 cell line (CCL-185)	LP	39	71	98	125			yes		[54]
Type 2 method: plaque assay	A549 cell line (CCL-185)	MP	7	18	28	47			yes		[54]
Type 2 method: LR-qPCR 6 kb fragment[c]	A549 cell line (CCL-185)	LP	5	20–50	100				yes		[54]
Type 2 method: LR-qPCR 6 kb fragment	A549 cell line (CCL-185)	MP	4	15–50	100				yes		[54]
Type 2 method: LR-qPCR 1 kb fragment	A549 cell line (CCL-185)	LP	18	50	100				yes		[54]
Type 2 method: LR-qPCR 1 kb fragment	A549 cell line (CCL-185)	MP	*5 + tailing*						yes		[54]
Type 2 method: LR-qPCR 10 kb fragment	A549 cell line (CCL-185)	LP	*15*						yes		[54]
Type 2 method: LR-qPCR 10 kb	A549 cell line (CCL-185)	MP	39	94					yes		[54]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
fragment											
Type 2 ATCC VR-846 method: MPN	A549 cell line (CCL-185)	LP	43	86	130	174			yes	Action spectrum	[55]
Type 2 ATCC VR-846, method: LR-PCR 1.1 kbp fragment[d]	A549 cell line (CCL-185)	LP	45	68					yes		[55]
Type 2 ATCC VR-846, method: LR-PCR 1.1 kbp fragment	A549 cell line (CCL-185)	Laser 254 nm	32	80–90 + tailing					yes		[55]
Type 2 ATCC VR-846 method: MPN	A549 cell line (CCL-185)	LP	40	76	120				yes		[55]
Type 2 ATCC VR-846 method: MPN	A549 cell line (CCL-185)	MP	8	18	34				yes	(b)	[55]
Type 2 ATCC VR-846 method: MPN	A549 cell line (CCL-185)	MP	32	71	135				yes	(e)	[55]
Type 2, method: cell culture	A549 cell line (CCL-185)	Laser 254 nm	40	70	101				yes		[55]
Type 2, method: infectivity	A549 cell line	LP	33	118					no		[56]
Type 2, method: qPCR[f]	A549 cell line	LP	*140*						no		[56]
Type 2, method: MPN	A549 cell line (CCL-185)	LP	47	86	129	172			yes		[57]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
Type 2, ATCC VR-846, method: ICC-qPCR[g]	A549 cell line (CCL-185)	LP	40	81	121	161			yes		[57]
Type 2 ATCC VR-846 method: ICC-qPCR	A549 cell line (ATCC CCL-185)	LP	16	37	69	117			yes		[16]
Type 2 ATCC VR-846 method: ICC-qPCR	A549 cell line (ATCC CCL-185)	MP	8.1	16	27	39	55		yes		[16]
Type 2 ATCC VR-846 method: ICC-qPCR	A549 cell line (ATCC CCL-185)	UV-LED 260 nm	16	41	79	121			yes	GF = 1.060	[16]
Type 2 ATCC VR-846 method: ICC-qPCR	A549 cell line (ATCC CCL-185)	UV-LED 280 nm	24	52	76	125	148		yes	GF = 1.270	[16]
Type 2 ATCC VR-846 method: cell culture (TCVA)	A549 cell line (ATCC CCL-185)	UV-LED 260 nm	44	73	103	118			yes	GF = 1.060	[16]
Type 2 ATCC VR-846 method: cell culture (TCVA)	A549 cell line (ATCC CCL-185)	UV-LED 280 nm	65	93	114	138			yes	GF = 1.270	[16]
Type 2, method: total culturable virus assay	A549 cell line (CCL-185)	LP	26	100	135	168	203	234	yes	(h)	[94]
Type 2 ATCC VR-846 method: soft agar overlay plaque assay	A549 cell line (CCL-185)	MP 224 nm	58	104	154	215			yes	GF = 9.584	[180]
Type 2	A549 cell	MP 254 nm	26	59	93	123			yes	Action	[180]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
ATCC VR-846 method: soft agar overlay plaque assay	line (CCL-185)									spectrum	
Type 2 ATCC VR-846 method: soft agar overlay plaque assay	A549 cell line (CCL-185)	MP 280 nm	44	79	108	137			yes	GF = 1.270	[180]
Type 2 ATCC VR-846 method: Soft agar overlay plaque assay	A549 cell line (CCL-185)	MP 218 nm	46	94	137				yes	GF = 13.183	[180]
Type 2 ATCC VR-846 method: soft agar overlay plaque assay	A549 cell line (CCL-185)	MP 228 nm	61	106	143	204			yes	GF = 7.129	[180]
Type 2 ATCC VR-846 method: soft agar overlay plaque assay	A549 cell line (CCL-185)	MP 232 nm	48	90	126	179			yes	GF = 4.684	[180]
Type 2 ATCC VR-846 method: soft agar overlay plaque assay	A549 cell line (CCL-185)	MP 239 nm	48	81	129				yes	GF = 1.262	[180]
Type 2 ATCC VR-846 method: soft agar overlay plaque assay	A549 cell line (CCL-185)	MP 248 nm	24	44	63	84			yes	GF = 0.546	[180]
Type 2 ATCC VR-846 method: soft agar overlay plaque assay	A549 cell line (CCL-185)	MP 260 nm	28	60	86	115			yes	GF = 1.060	[180]
Type 2 ATCC VR-846 method: soft	A549 cell line (CCL-185)	MP 265 nm	30	73	109				yes	GF = 1.330	[180]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
agar overlay plaque assay											
Type 2 ATCC VR-846 method: soft agar overlay plaque assay	A549 cell line (CCL-185)	MP 270 nm	22	64	103	146			yes	GF = 1.610	[180]
Type 2 ATCC VR-846 method: soft agar overlay plaque assay	A549 cell line (CCL-185)	MP 289 nm	42	77	104	131			yes	GF = 0.677	[180]
Type 2 ATCC VR-846 method: soft agar overlay plaque assay	A549 cell line (CCL-185)	MP	25	40	64	82			yes		[180]
Type 2 VR-846 method: plaque assay	A549 cell line (ATCC CCL-185)	Microplasma UV 222 nm	59	151	243	282			yes	GF = 10.799	[181]
Type 2 VR-846 method: plaque assay	A549 cell line (ATCC CCL-185)	MP 223 nm	71	110	197				yes	GF = 10.193	[181]
Type 4, ATCC VR-1572, method: ICC qPCR	PLC/PRF5 ATCC CRL-8024	LP	10	34	69	116			yes		[66]
Type 5, method: cell culture	HEK 293 cells human embryonic kidney	LP	45	76	120				yes		[63]
Type 5	HEK293	LP	38	76	114	152			yes		[182]
Type 5	HEK293	MP	23	45	68	90			yes		[182]
Type 5	PLC/PRF5	LP	31	62	93	123			yes		[182]
Type 5	PLC/PRF5	MP	22	43	65	87			yes		[182]
Type 5	XP17BE	LP	13	26	39	52			yes		[182]
Type 5	XP17BE	MP	9	18	27	36			yes		[182]
Type 5	A549 cell line (CCL-185)	LP	51	101	151				yes		[29]
Type 5	A549 cell line (CCL-	LP	63	100	151				yes		[67]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
	185)										
Type 5 ATCC VR5	A549 cell line (CCL-185)	UV-LED 285 nm	47	77	119				yes	GF = 0.942	[151]
Serotype 5 ATCC VR5	A549 cell line (ATCC CCL-185)	UV-LED 280 nm	55	95	156				yes	GF = 1.270	[151]
Type 6, method: MPN	PLC/ PRF5 and HeLa cell line	LP	39	77	115	154			yes		[179]
Type 40, strain: Dugan	PLC/PRF5 cell line	LP	50	109	167				yes		[68]
Type 40, method: MPN	PLC/PRF5 cell line	MP	16	23	~30	~40			yes		[60]
Type 40, method: MPN	PLC/PRF5 cell line	LP	63	88	109	>120			yes		[69]
Type 40	HEK293	LP	35	70	105	139			yes		[182]
Type 40	HEK293	MP	17	33	50	66			yes		[182]
Type 40	PLC/PRF5	LP	34	67	101	134			yes		[182]
Type 40	PLC/PRF5	MP	16	33	49	65			yes		[182]
Type 41, ATCC VR-930, method: ICC-RT-PCR[i]	HEK 293 cells ATCC CRL-1573	LP	56	111	167	222			yes		[70]
Type 41, method: cell culture	HEK 293 cells human embryonic kidney & PLC/PRF5 (hepatoma) cells	LP	62	120					yes		[63]
Type 41	HEK293	LP	45	91	136	182			yes		[182]
Type 41	HEK293	MP	20	39	59	78			yes		[182]
Type 41	PLC/PRF5	LP	34	68	103	137			yes		[182]
Type 41	PLC/PRF5	MP	18	36	53	71			yes		[182]
Type 41	XP17BE	LP	14	29	43	57			yes		[182]
Type 41	XP17BE	MP	11	21	32	42			yes		[182]
Atlantic											

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
halibut nodavirus (AHNV)	SSN-1 cell line	LP	35	70	104	140	176	211	yes		[183]
B40-8 (phage)											
	B. fragilis HSP-40	LP	12	18	23	28			yes		[21]
	B. fragilis	LP	11	17	23	29	35	41	yes		[24]
Calicivirus feline											
	CRFK cell line	LP	5	15	23	30	39		yes		[68]
	MDCK cell line[j]	LP	7	15	22	30	36		yes		[184]
	CRFK cell line	LP	7	16	25				yes		[184]
FCV ATCC VR-782	Crandell Reese feline kidney cell CRfk, ATCC CCL-94	LP	5	12	18	26			yes		[71]
ATCC VR-782	CRFK cells ATCC CCL-94	UV-LED 265 nm	8.3	15	23	31			yes	GF = 0.941	[110, 185]
ATCC VR-782	CRFK cells ATCC CCL-94	UV-LED 280 nm	4.8	9	14	19			yes	GF = 0.486	[110, 185]
ATCC VR-782	CRFK cells ATCC CCL-94	UV-LED 300 nm	5.3	11	16	22			yes	GF = 0.037	[110, 185]
FCV strain F4 method: TCID50	CRFK cells	Excilamp 222 nm	2.3	6.2	15				no	GF = 0.683	[86]
FCV strain F4 method: TCID50	CRFK cells	LP	3.5	8.2	27				no		[86]
Coronavirus											
HCoV-229E method: TCID50	Human lung fibroblast MRC-5 cell line (ATCC CCL-171)	Filtered KrCl excilamp 222 nm	0.7	1.4					yes	GF = 0.683	[72]
HcoV-229E method:	Human lung fibroblast	Unfiltered KrCl excilamp	0.7	1.4	1.9				yes		[72]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
TCID50	MRC-5 cell line (ATCC CCL-171)	222/258 nm									
HcoV-229E method: TCID50	Human lung fibroblast MRC-5 cell line (ATCC CCL-171)	LP	1.7	3.2					yes		[72]
HcoV-229E method: TCID50	Human lung fibroblast MRC-5 cell line (ATCC CCL-171)	UV-LED 270 nm	1.9	3.6	5.6				yes	GF = 0.813	[72]
HcoV-229E method: TCID50	Human lung fibroblast MRC-5 cell line (ATCC CCL-171)	UV-LED 282 nm	0.8	2.9	4.9				yes	GF = 0.421	[72]
HcoV-229E VR-740 method: TCID50	MRC-5 cells (CCL-171)	KrCl excilamp 222 nm	0.6	1.1	1.7					Medium: air	[186]
HcoV-OC43 VR-1558 method: TCID50	WI-36 (CCL-75)	KrCl excilamp 222 nm	0.4	0.8	1.2	1.6				Medium: air	[186]
HcoV-OC43 method: RT-qPCR (ICC-RTqPCR)	MRC-5 cells	UV-LED 267 nm	3	4.5	5.1	6.1			yes	GF = 0.894	[187]
HcoV-OC43 method: RT-qPCR (ICC-RTqPCR)	MRC-5 cells	UV-LED 279 nm	1.8	2.9	3.6	4.5			yes	GF = 0.519	[187]
HcoV-OC43 method: RT-qPCR (ICC-RTqPCR)	MRC-5 cells	UV-LED 286 nm	1.8	2.9	3.9	5			yes	GF = 0.302	[187]
HcoV-OC43 method: RT-qPCR (ICC-RTqPCR)	MRC-5 cells	UV-LED 297 nm	1.2	1.9	2.2	3.3			yes	GF = 0.070	[187]
MERS-CoV method: plaque assay	Vero 81 cells	LP	0.8 min	1.7 min	2.5 min	3.4 min	4.2 min		no	Virus droplets	[188]
MERS-CoV (HcoV-EMC-	VeroE6 cells ATCC	LP	17	35	57				no	Medium: blood	[189]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
2012) method: TCID50	CCL-22									platelet concentrate	
SARS-CoV-P9 method: TCID50	VeroE6 cells	UV 260 nm						325	no	GF = 1.026	[190]
SARS-CoV Urbani strain method: TCID50	VeroE6 cells	LP	187	418	779	1215			no		[191]
SARS-CoV Hanoi strain method: TCID50	VeroE6 cells	UV	12	23	38	69	101		no	Solid surface	[192]
SARS-CoV strain Frankfurt 1 method: TCID50	VeroE6 cells ATCC CCL-22	LP	16	33	49				no	Medium: blood platelet concentrate	[193]
SARS-CoV-2 (2019-n-CoV/Italy-INMI1) method: real-time PCR using the 2019-nCoV CDC qPCR probe assay	VeroE6 cells	LP	Complete removal at 3.7 mJ cm^{-2}						yes	(h) Initial concentration: 0.05 MOI[k]	[194]
SARS-CoV-2 (2019-n-CoV/Italy-INMI1) method: real-time PCR using the 2019-nCoV CDC qPCR probe assay	VeroE6 cells	LP	1.1	2.2	3.4				yes	(h) Initial concentration: 5 MOI – 24 h postinfection – N1	[194]
SARS-CoV-2 (2019-n-CoV/Italy-INMI1) method: real-time PCR using the 2019-nCoV CDC qPCR probe assay	VeroE6 cells	LP	0.8	1.6	2.5	3.3	28		yes	(h) Initial concentration: 5 MOI – 24 h postinfection – N2	[194]
SARS-CoV-	VeroE6	LP	0.6	1.3	1.9	2.6	3.2		yes	(h)	[194]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
2 (2019-n-CoV/Italy-INMI1) method: real-time PCR using the 2019-nCoV CDC qPCR probe assay	cells									Initial concentration: 5 MOI – 48 h postinfection – N1	
SARS-CoV-2 (2019-n-CoV/Italy-INMI1) method: real-time PCR using the 2019-nCoV CDC qPCR probe assay	VeroE6 cells	LP	0.6	1.2	1.8	2.4	3		yes	(h) Initial concentration: 5 MOI – 48 h postinfection – N2	[194]
SARS-CoV-2 (2019-n-CoV/Italy-INMI1) method: real-time PCR using the 2019-nCoV CDC qPCR probe assay	VeroE6 cells	LP	0.6	1.2	1.8	2.4	3		yes	(h) Initial concentration: 5 MOI – 72 h postinfection – N1	[194]
SARS-CoV-2 (2019-n-CoV/Italy-INMI1) method: real-time PCR using the 2019-nCoV CDC qPCR probe assay	VeroE6 cells	LP	0.6	1.1	1.7	2.3	2.8		yes	(h) Initial concentration: 5 MOI – 72 h postinfection – N2	[194]
SARS-CoV-2 (2019-n-CoV/Italy-INMI1) method: real-time PCR using the 2019-nCoV CDC qPCR probe assay	VeroE6 cells	LP	1.4	2.8	7.9				yes	(h) Initial concentration: 1000 MOI – 24 h postinfection – N1	[194]
SARS-CoV-2 (2019-n-CoV/Italy-INMI1)	VeroE6 cells	LP	1.1	2.2	3.4	15			yes	(h) Initial concentration: 1000	[194]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
method: real-time PCR using the 2019-nCoV CDC qPCR probe assay										MOI – 24 h postinfection – N2	
SARS-CoV-2 (2019-n-CoV/Italy-INMI1) method: real-time PCR using the 2019-nCoV CDC qPCR probe assay	VeroE6 cells	LP	3.7	7.8	12	16			yes	(h) Initial concentration: 1000 MOI – 48 h postinfection – N1	[194]
SARS-CoV-2 (2019-n-CoV/Italy-INMI1) method: real-time PCR using the 2019-nCoV CDC qPCR probe assay	VeroE6 cells	LP	3	6.7	11	15			yes	(h) Initial concentration: 1000 MOI – 48 h postinfection – N2	[194]
SARS-CoV-2 (2019-n-CoV/Italy-INMI1) method: real-time PCR using the 2019-nCoV CDC qPCR probe assay	VeroE6 cells	LP	5.2	8.3	11	14			yes	(h) Initial concentration: 1000 MOI – 72 h postinfection – N1	[194]
SARS-CoV-2 (2019-n-CoV/Italy-INMI1) method: real-time PCR using the 2019-nCoV CDC qPCR probe assay	VeroE6 cells	LP	4.8	7.9	11	14	84		yes	(h) Initial concentration: 1000 MOI – 72 h postinfection – N2	[194]
SARS-CoV-2 method: end-point dilution assay	VeroE6 cells	UVA 365 nm	292	427					no		[195]
SARS-CoV-2	VeroE6 cells	LP	62	129	243	400	720		no		[195]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
method: end-point dilution assay											
SARS-CoV-2 (Hu/DP/Kng/19-027, LC528233)	Vero cells	Deep UV-LED 280 nm	2.6	10	32				no	GF = 0.486	[196]
SARS-CoV-2 (isolate SARS-CoV-2/human/Liverpool/REMRQ0001/2020) method: TCID50	VeroE6 cells C1008	UV 254 nm	35	70	118	181	226		no		[197]
SARS-CoV-2 (isolate SARS-CoV-2/human/Liverpool/REMRQ0001/2020) method: plaque assay	VeroE6 cells C1008	UV 254 nm	43	85	135	182	208		no		[197]
SARS-CoV-2 method: plaque assay	VeroE6 cells	LP	1.3 s	3.4 s					yes	Dried virus droplets	[198]
SARS-CoV-2 method: plaque assay	VeroE6 cells	LP	1.7 s	3.5 s					yes	Wet virus droplets	[198]
SARS-CoV-2 Isolate USA-WA1/2020, BEI Resources, Batch #: 70034262 method: plaque assay	Vero cells ATCC clone E6	KrCl excilamp 222 nm (> 240 nm filtered)	0.9	1.6	2.3	3.8			yes	GF = 0.683	[199]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
Coxsackievirus											
A10 (CVA10, Kowalik strain) method: ICC-RTqPCR	BGMK cells[l]	UV-LED 260 nm	4.6	8.9	13				yes	GF = 1.026	[200]
A10 (CVA10, Kowalik strain) method: ICC-RTqPCR	BGMK cells	UV-LED 280 nm	3.8	6	7.6	9.3			yes	GF = 0.486	[200]
B1 L071615 method: MPN	BGMK cells	LP	7.2	17	23				no		[201]
B3	BGM cell line	LP	8	16	25	33			yes		[52]
B4	BGM cell line	LP	7	13	18	24	29		yes		[59]
B4 M063015 method: MPN	BGMK cells	LP	4.3	10	19	23	30		no		[201]
B4 T051217 method: MPN	BGMK cells	LP	6.5	11	18	25	31		no		[201]
B5	BGM cell line	LP	9.5	18	27	36			yes		[52]
B5	BGM cell line	LP	7	14	21				yes		[73]
B5 (Faulkner) method: MPN	BGMK cells	LP	5.9	12	17	26	32		no		[201]
B5 (L030315) method: MPN	BGMK cells	LP	4.2	9.8	19	27	32		no		[201]
B5 (L060815) method: MPN	BGMK cells	LP	4.1	11	18	25	31		no		[201]
B5 (L061815) method: MPN	BGMK cells	LP	5.1	11	18	27			no		[201]
B5 (L070215) method: MPN	BGMK cells	LP	5.6	12	16	28			no		[201]
B5 (L070915) method: MPN	BGMK cells	LP	3.8	11	17	23	31		no		[201]
B5	BGMK	LP	4.3	10	16	23	32		no		[201]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
(M063015) method: MPN	cells										
EV70 (J670/71 strain) method: ICC-RTqPCR	BGMK cells	UV-LED 260 nm	3.3	10					yes	GF = 1.026	[200]
EV70 (J670/71 strain) method: ICC-RTqPCR	BGMK cells	UV-LED 280 nm	2	5.8					yes	GF = 0.486	[200]
Crimean-Congo hemorrhagic fever virus											
CCHFV-strain Afg09-2990 method: TCID50	Huh7 cells JCRB 0403	LP	20	41					no	Medium: blood platelet concentrate	[193]
Echovirus											
I	BGM cell line	LP	8	17	25	33			yes		[52]
II	BGM cell line	LP	7	14	21	28			yes		[52]
II ATCC VR737 method: MPN	BGMK cells	LP	6.2	13	19	30	40		no		[202]
II Wild type method: MPN	BGMK cells	LP	5.2	11	19	28	40		no		[203]
II ATCC VR41 method: MPN	BGMK cells	LP	5.8	12	20	26	33		no		[201]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
12	Fetal rhesus monkey kidney cell FRhK-4, ATCC CRL-1688	LP	8	13	18	28	40		yes		[71]
30 (Bastianni strain) method: ICC-RTqPCR	BGMK cells	UV-LED 260 nm	4.2						yes	GF = 1.026	[200]
30 (Bastianni strain) method: ICC-RTqPCR	BGMK cells	UV-LED 280 nm	3.4	7.3					yes	GF = 0.486	[200]
GA phage	*E. coli* Hfr K12 ATCC 23631	LP	18	38	58	87	121		yes		[204]
Hepatitis											
A HM175	FRhK-4 cell	LP	5.4	15	25	35			yes		[115]
A HM175	FRhK-4 cell	LP	4	8	12	16			yes		[73]
A	HAV/HFS/ GBM	LP	*6*	*10*	*15*	*21*			no		[205]
HEV-p6-kernow method: qRT-PCR	HepG2/C3 A cells ATCC CRL-10741	LP	6.5	12	18	23	30		yes	(h)	[74]
HS2 bacteriophage											
method: plaque assay	*Pseudoalteromonas* 13-15	LP	4.1	8.2	12	17	21		yes		[206]
Infectious pancreatic necrosis virus (IPNV)	BF-2 cell line	LP	82	165	246	325			yes		[183]
Infectious salmon anemia virus (ISAV)	SHK-1 cell line	LP	2.5	5.0	7.5				yes		[183]
Influenza A virus											
H1N1 (A/PR/8/34) method: fluorescent	MDCK cells	LP	0.7							Medium: air – 25 % relative humidity	[207]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
focus reduction assay										(RH)	
H1N1 (A/PR/8/34) method: fluorescent focus reduction assay	MDCK cells	LP	1							Medium: air – 50 % RH	[207]
H1N1 (A/PR/8/34) method: fluorescent focus reduction assay	MDCK cells	LP	1							Medium: air – 75 % RH	[207]
IAV H1N1 (strain A/Puerto Rico/8/1934) method: plaque assay	MDCK cells	UVA-LED 365 nm	5663	54219					yes		[208]
IAV H1N1 (strain A/Puerto Rico/8/1934) method: plaque assay	MDCK cells	UVB-LED 310 nm	211	466	1081				yes		[208]
IAV H1N1 (strain A/Puerto Rico/8/1934) method: plaque assay	MDCK cells	UVC-LED 280 nm	7.5	15	24	27			yes	GF = 0.486	[208]
JC polyomavirus											
Mad-4 method: cell culture	SVG-A cells	LP	*60*	*124*	*171*				no		[56]
Mad-4 method: qPCR	SVG-A cells	LP	*>180*						no		[56]
MS2 coliphage											
	N/A	UV-LED 255 nm	15	28	40				yes	GF = 1.057	[209]
	E. coli Famp	LP	13	25	44	64			yes		[76]
	E. coli Famp	MP	9	17	31	46	56		yes		[76]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
	E. coli Cr63	LP	17	34					yes		[210]
	E. coli C3000	LP	35						yes		[73]
	E. coli ATCC15597	LP?	19	40	61				no		[77]
	Salmonella typhimurium WG49	LP	16	35	57	83	114	152	no		[211]
	E. coli ATCC15597	LP	13	29	45	62	80		yes		[78]
	E. coli C3000	LP	13	28					yes		[42]
	E. coli K-12 Hfr	LP	21	36					yes		[21]
	E. coli K-12	LP	19	36	55				yes		[24]
	E. coli C3000	LP	20	42	68	90			yes		[48]
	E. coli ATCC 15977	LP	20	50	85	120			yes		[68]
	E. coli ATCC 15977	LP	20	42	70	98	133		no		[212]
	E. coli C3000	LP	20	42	69	92			yes		[213]
	E. coli ATCC 15977	LP	29	58	87	116			yes		[179]
	E. coli ATCC 15977	LP	14	33	50	66			yes		[156]
	E. coli K12 A/λ(F+)	LP	22	48					yes		[29]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
method: plaque assay	*E. coli* Famp ATCC 700891	LP	14	30	45	60	77		yes		[15]
method: plaque assay	*E. coli* Famp ATCC 700891	UV-LED 260 nm	16	44	49	65	79		yes	GF = 1.220	[15]
method: cell culture	*Salmonella typhimurium* WG49	LP	20	40	61	91	119	146	no		[56]
method: qPCR	*Salmonella typhimurium* WG49	LP	*<180*						no		[56]
method: qRT-PCR	*Salmonella* WG49	LP	12	23	33	44	104		yes	(h)	[74]
ATCC15977-B1	*E. coli* ATCC 15977	LP	17	38	59	81	103	123	yes		[115]
ATCC15977-B1	*E. coli* HS(pFamp)R	LP	16	45	72	100	128	154	yes		[214]
ATCC15977-B1	*E. coli* ATCC 15977	LP	15	32	51	72	98		yes		[212]
ATCC15977-B1	*E. coli* ATCC 15977	LP	25	42	66	97			yes		[215]
ATCC15977-B1	*E. coli* ATCC 15977	LP	20	40	62	92	141	173	yes		[70]
ATCC15977-B1	*E. coli* ATCC 15977	LP	20	40	62	92	141	173	yes		[70]
ATCC15977-B1	*E. coli* ATCC 15977	LP	18	38	59	80			yes		[105]
ATCC15977-B1	*E. coli* NCTC12486	LP	20	40	60				yes	Action spectrum	[101]
ATCC15977-B1	*E. coli* Hfr K12 ATCC 23631	LP	20	40	68	95	125		yes		[204]
ATCC15977-B1	*E. coli* ATCC 15597	LP	18	40					yes		[216]
	E. coli										

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
ATCC15977-B1	ATCC 15597 C3000	LP	14	29	45				yes		[102]
ATCC15977-B1	*E. coli* Famp	LP	*16*	*>30*					yes		[217]
ATCC15977-B1	*E. coli* ATCC 15597	LP	20	39	61	83			yes		[69]
ATCC15977-B1	*E. coli* ATCC 15597	LP	18	41					yes		[130]
ATCC15977-B1	*E. coli* ATCC 15597	UV-LED 255 nm	26	53					yes	GF = 1.057	[130]
ATCC15977-B1	*E. coli* ATCC 15597	UV-LED 275 nm	24	52					yes	GF = 0.952	[130]
ATCC15977-B1	*E. coli* Famp ATCC 700891	LP	14	32	51				yes		[71]
ATCC15977-B1	N/A	LP	13	30	53	70			yes		[218]
ATCC15977-B1	*E. coli* ATCC 15597 Migula	LP	18	52	75	92	106	116	yes		[219]
ATCC15977-B1	*E. coli* ATCC 15597	LP	20	40	70	95	120	138	no		[220]
ATCC15977-B1	*E. coli* ATCC 15597 C3000	LP	20	45					yes		[221]
ATCC15977-B1	*E. coli* ATCC 15597 C3000	UV-LED 260 nm	18	39	59				yes	GF = 1.220	[221]
ATCC15977-B1	*E. coli* ER2738	UV-LED 255 nm	20	44	76				no	GF = 1.057	[222]
ATCC15977-B1	*E. coli* Hfr K12 ATCC2363	LP	6	13	21	29	37	46	yes		[223]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
	1										
ATCC15977-B1	*E. coli* HS(pFamp)R ATCC 700891	LP	18	33	63				yes	Action spectrum	[79]
ATCC15977-B1 (Action spectrum weighted fluence)	*E. coli* HS(pFamp)R ATCC 700891	MP	15	32	52				yes	Action spectrum	[79]
ATCC15977-B1	*E. coli* HS(pFamp)R ATCC 700891	LP	20	40	60				yes	Action spectrum	[224]
ATCC 15597-B1 method: EPA 1601	*E. coli* (Famp) ATCC 700891	MP	15	32	48				yes		[16]
ATCC 15597-B1 method: EPA 1601	*E. coli* (Famp) ATCC 700891	UV-LED 260 nm	15	35	55				yes	GF = 1.220	[16]
ATCC 15597-B1 method: EPA 1601	*E. coli* (Famp) ATCC 700891	UV-LED 280 nm	14	30	46				yes	GF = 0.780	[16]
ATCC15977-B1	*E. coli* K12 A/λ(F+)	UV-LED 285 nm	19	41	61				yes	GF = 0.579	[151]
ATCC15977-B1	*E. coli* Famp ATCC 700891	LP	17	35	60	88	116		yes	(h)	[94]
ATCC 15597-B1 method: double agar layer	*E. coli* K12 A/λ(F+)	UV-LED 280 nm	25	55	81	109			yes	GF = 0.780	[151]
ATCC	*E. coli* K12	LP	62 mJ cm^{-2} for 0.4 log reduction						yes		[225]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
15597-B1 method: RT-qPCR	A/λ(F+) ATCC 10798										
ATCC 15597-B1 method: double agar layer	*E. coli* ATCC 15597	LP	44	75	106				yes		[226]
ATCC 15597-B1 method: double agar layer	*E. coli* C3000 ATCC 15597	LP			7.4		75		no		[227]
ATCC 15597-B1 method: double agar layer	*E. coli* C3000 ATCC 15597	UV-LED 266 nm			2		6.1		no	GF = 1.199	[227]
ATCC 15597-B1 method: double agar layer	*E. coli* C3000 ATCC 15597	UV-LED 279 nm			1.3		5.6		no	GF = 0.817	[227]
ATCC 15597-B1 method: single agar layer	*E. coli* Famp ATCC 700891	LP	17	36	59	90			yes	Action spectrum	[228]
ATCC 15597-B1 method: single agar layer	*E. coli* Famp ATCC 700891	UV-LED 255 nm	12	28	47				yes	GF = 1.057	[228]
ATCC 15597-B1 method: single agar layer	*E. coli* Famp ATCC 700891	UV-LED 265 nm	15	37	60				yes	GF = 1.216	[228]
ATCC 15597-B1 method: single agar	*E. coli* Famp ATCC 700891	UV-LED 285 nm	14	30	52				yes	GF = 0.579	[228]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
layer											
ATCC 15597-B1 method: single agar layer	*E. coli* Famp ATCC 700891	KrCl excilamp 222 nm	15	28	45	62	90		yes	GF = 2.086	[228]
ATCC 15597-B1 method: plaque assay	*E. coli* ATCC 15597	LP	13	35	54				yes	Action spectrum	[135]
ATCC 15597-B1 method: plaque assay	*E. coli* ATCC 15597	XeBr excilamp 282 nm	15	47					yes	GF = 0.703	[135]
ATCC 15597-B1 method: plaque assay	*E. coli* ATCC 15597	MP 310 nm	20						yes	GF = 0.227	[135]
ATCC 15597-B1 method: double agar layer	*E. coli* K12 A/λ(F+)	UV-LED 265 nm	22	59	93	128			yes	GF = 1.216	[110, 185]
ATCC 15597-B1 method: double agar layer	*E. coli* K12 A/λ(F+)	UV-LED 280 nm	24	46	73	95			yes	GF = 0.780	[110, 185]
ATCC 15597-B1 method: double agar layer	*E. coli* K12 A/λ(F+)	UV-LED 300 nm	1.7	3.8	5.6	7.3			yes	GF = 0.005	[110, 185]
ATCC 15597-B1 method: single agar layer	*E. coli* Famp ATCC 700891	LP	14	32					yes	Action spectrum	[28]
ATCC 15597-B1	*E. coli* Famp ATCC	UV-LED 255 nm	13	26	40				yes	GF = 1.057	[28]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
method: single agar layer	700891										
ATCC 15597-B1 method: single agar layer	*E. coli* Famp ATCC 700891	UV-LED 265 nm	16	35					yes	GF = 1.216	[28]
ATCC 15597-B1 method: single agar layer	*E. coli* Famp ATCC 700891	UV-LED 285 nm	13						yes	GF = 0.579	[28]
ATCC 15597-B1 method: double agar layer	*E. coli* ATCC 15597	UV-LED 265 nm	16	33	54	73			yes	GF = 1.216	[132]
ATCC 15597-B1 method: double agar layer	*E. coli* ATCC 15597	UV-LED 265 nm	27	55	87	121	154		yes	GF = 1.216	[157]
ATCC 15597-B1 method: double agar layer	*E. coli* ATCC 15597	UV-LED 285 nm	46	86	133	172			yes	GF = 0.579	[157]
F-specific	*E. coli* WG21	LP	8	17	25	33			yes		[229]
F-specific	*E. coli* WG21	MP	9	19	28	38			yes		[229]
ATCC15977-B1 F-specific	*E. coli* C3000	LP	14	29	49				yes		[59]
ATCC15977-B1 F-specific	*E. coli* ATCC 15597 C3000	LP	19	42	69				yes		[65]
ATCC15977-B1 F-specific	*E. coli* ATCC 15597 C3000	MP	16	33	53	90			yes		[65]
ATCC 15597-B1 F-specific method:	*E. coli* ATCC 15597	LP	38	64	90				yes		[230]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
double agar layer											
ATCC 15597-B1 F-specific method: double agar layer	*E. coli* ATCC 15597	UV-LED 270 nm	110						yes	GF = 1.100	[230]
ATCC15977-B1	*E. coli* Hfr (*c*-3000)	LP	17	39	65	96	130		yes		[75]
ATCC 16696-B1	*E. coli* Famp ATCC 700891	LP	30	54	87	121			yes		[231]
Coliphage 1 F-specific method: double agar layer	*E. coli* ATCC 15597	LP	16	28	39	51	62		yes		[230]
Coliphage 1 F-specific method: double agar layer	*E. coli* ATCC 15597	UV-LED 270 nm	8.8	18	35	72			yes	GF = 1.100	[230]
Coliphage 5 F-specific method: double agar layer	*E. coli* ATCC 15597	LP	29	47	61	77	94		yes		[230]
Coliphage 5 F-specific method: double agar layer	*E. coli* ATCC 15597	UV-LED 270 nm	24	44	56	74	122		yes	GF = 1.100	[230]
Coliphage 7 (somatic coliphage) method: double agar layer	*E. coli* ATCC 13706	LP	4.9	9.8	15	20	31		yes		[230]
Coliphage 7 (somatic coliphage) method: double agar layer	*E. coli* ATCC 13706	UV-LED 270 nm	8	16	44	57	121		yes	GF = 1.100	[230]
Coliphage	*E. coli*	LP	12	25	43	62			yes		[230]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
17 (somatic coliphage) method: double agar layer	ATCC 13706										
Coliphage 17 (somatic coliphage) method: double agar layer	*E. coli* ATCC 13706	UV-LED 270 nm	14	47	57	78			yes	GF = 1.100	[230]
DSM5694	*E. coli* NCIB 9481	LP?	4	16	38	68	110		no		[205]
DSMZ 13767 method: double agar layer	*E. coli* DSMZ 5695	LP	4.3	10	16	22	32		no		[201]
Single-stranded RNA (3.6) method: double agar layer	*E. coli* Famp	LP	19						yes		[232]
Single-stranded RNA (3.6) method: double agar layer	*E. coli* Famp	MP	8.6	19	31				yes		[232]
Myoviridae	*E. coli* C	LP	1.8	3.6	5.1	6.7	8.5		yes		[59]
Murine norovirus											
NCIMB10108	RAW 264.7 cells	LP	10	15	22	27	30		yes		[217]
CW3	RAW 264.7 macrophags ATCC TIB-71	LP	10	15	22	27	30		yes		[71]
method: Plaque assay	RAW 264.7 cells	LP	6	13	19	24			yes		[231]
Murine hepatitis virus (MHV)											
method: plaque assay	DBT cells	UV 254 nm	5.6 min							Medium: air – 0.6 mJ cm^{-2} for 0.9 log reduction	[233]
A59 method:	Hela cells	LP	1.9 min	3.7 min	5.4 min	6.9 min	8.3 min		no	Virus droplets	[188]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
plaque assay											
A59 method: plaque assay	DBT cells	LP	0.4	0.9	1.4	1.8	3		yes		[206]
A59 method: TCID50	DBT cells	Filtered KrCl excilamp 222 nm	0.6	2	2.3				yes	GF = 0.683	[72]
A59 method: TCID50	DBT cells	Unfiltered KrCl excilamp 222/258 nm	1.1	1.5					yes		[72]
A59 method: TCID50	DBT cells	LP	1	2.1	3.2				yes		[72]
A59 method: TCID50	DBT cells	UV-LED 270 nm	1	1.9					yes	GF = 0.813	[72]
A59 method: TCID50	DBT cells	UV-LED 282 nm	0.8	2					yes	GF = 0.421	[72]
Nipah virus NiV-strain Malaysia method: TCID50	Vero 76 cells ATCC CRL-1587	LP	21	43					no	Medium: blood platelet concentrate	[193]
Phage B124-54	*B. fragilis* strain GB-124	LP	14	21	28				yes		[234]
PHI 6											
method: plaque assay	*Pseudomonas syringae*	Filtered KrCl excilamp 222 nm	2.2	4	5.4				yes	GF = 0.683	[72]
method: plaque assay	*Pseudomonas syringae*	Unfiltered KrCl excilamp 222/258 nm	4.9	7.6	10.4				yes		[72]
method: plaque assay	*Pseudomonas syringae*	LP	30	71					yes		[72]
method: plaque assay	*Pseudomonas syringae*	UV-LED 270 nm	25	53	77				yes	GF = 0.813	[72]
method: plaque assay	*Pseudomonas syringae*	UV-LED 282 nm	17	35	49				yes	GF = 0.421	[72]
PHI X 174											
(phage)	*E. coli* C3000	LP?	2.1	4.2	6.4	8.5	11	13	yes		[73]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
(phage)	*E. coli* ATCC 15597	LP?	*4*	*8*	*12*				no		[77]
(phage)	*E. coli* WG5	LP	2.2	5.3	7.3	11			yes		[21]
(phage)	*E. coli* ATCC 13706	LP	2.0	3.5	5	7			yes		[20]
(phage)	*E. coli* WG5	LP	3	5	7.5	10	13	15	yes		[24]
	N/A	UV-LED 255 nm	1.6	3.4	5.3				yes	GF = 1.030	[209]
	N/A	UV-LED 280 nm	2.3	5	8.4				yes	GF = 0.980	[209]
ATCC 13706	N/A	LP	7.1	14	21	28	37	47	yes		[218]
ATCC 13706-B1 method: double agar layer	*E. coli* CN13 ATCC 700609	LP			3.7		36		no		[227]
ATCC 13706-B1 method: double agar layer	*E. coli* CN13 ATCC 700609	UV-LED 266 nm			4.1		14		no	GF = 1.238	[227]
ATCC 13706-B1 method: double agar layer	*E. coli* CN13 ATCC 700609	UV-LED 279 nm			4.4		17		no	GF = 1.013	[227]
DSM 4497 method: qPCR	*E. coli* DSM 13127	LP	30	57	86	122	148		yes		[235]
Single-stranded DNA (5.3) method: double agar layer	*E. coli* CN13	LP	2.4	4.7	12	26			yes		[232]
Single-stranded DNA (5.3) method: double agar layer	*E. coli* CN13	MP	2.1	4.2	14				yes		[232]
	E. coli CN13	LP	N/A	N/A	N/A	8.9			yes		[76]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
	E. coli CN13	MP	N/A	N/A	N/A	6.7			yes		[76]
Picornaviridae aphthovirus (foot and mouth disease virus)											
O189	Baby hamster kidney (BHK-21) cell line	LP	25	50	75	100			no	(h)	[236]
A132	Baby hamster kidney (BHK-21) cell line	LP	20	39	59	78			no	(h)	[236]
A Sakol	Baby hamster kidney (BHK-21) cell line	LP	22	44	67	89			no	(h)	[236]
AS 1	Baby hamster kidney (BHK-21) cell line	LP	31	63	94	125			no	(h)	[236]
Poliovirus											
Type 1 LSc2ab	MA104 cells	LP	N/A	5.6	11	17	22		yes		[97]
Type 1 ATCC Mahoney	N/A	LP	6	14	23	30			yes		[126]
Type 1 LSc2ab	BGM cell line	LP	2.8	11	20	28	37	46	yes		[115]
Type 1	BGM cell line	LP	8.0	16	23	31			yes		[52]
Type 1 LSc2ab	BGM cell line	LP	7	17	28	37			yes		[214]
Vaccine strain method: plaque assay	N/A	LP	6.4	14	22	33			no		[212]
Vaccine strain method: TCID50	N/A	LP	6.4	14	21	31			no		[212]
Type 1	BGM cell line	LP	8.7	17	25				yes		[59]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
Type 1	BGM cell line	LP	7	14	21	29	39	50 + tailing	yes		[204]
Type 1 (Mahoney strain) method: ICC-RTqPCR	BGMK cells	UV-LED 260 nm	3.5	7.6	12				yes	GF = 1.026	[200]
Type 1 (Mahoney strain) method: ICC-RTqPCR	BGMK cells	UV-LED 280 nm	3.2	5.4	6.9	9.2			yes	GF = 0.486	[200]
PRD-1 (Tectiviridae)											
Phage	*Salmonella typhimurium* Lt2	LP	10	17	24	30			yes		[78]
ATCC BAA-769-B1	*Salmonella typhimurium* Lt2	LP	18	50	81	108	138		yes		[59]
	Salmonella typhimurium Lt2	LP	N/A	N/A	N/A	36			yes		[76]
	Salmonella typhimurium Lt2	MP	N/A	N/A	N/A	32			yes		[76]
Double-stranded DNA (14.7) method: double agar layer	*Salmonella typhimurium* Lt2	LP	14	26					yes		[232]
Double-stranded DNA (14.7) method: double agar layer	*Salmonella typhimurium* Lt2	MP	11	23	35				yes		[232]
Qβ											
	N/A	UV-LED 255 nm	12	24					yes	GF = 1.063	[209]
	N/A	UV-LED 280 nm	*19*						yes	GF = 0.720	[209]
	E. coli ATCC 15597 C3000	LP	12	25	40				yes		[221]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
	E. coli ATCC 15597 C3000	UV-LED 260 nm	11	24	36	51			yes	GF = 1.240	[221]
ATCC 15597-B1 method: double agar layer	*E. coli* K12 A/λ(F+) ATCC 10798	LP	11	24					yes	Action spectrum	[27]
ATCC 15597-B1 method: double agar layer	*E. coli* K12 A/λ(F+) ATCC 10798	UV-LED 265 nm	11	26	38	51			yes	GF = 1.236	[27]
ATCC 15597-B1 method: double agar layer	*E. coli* K12 A/λ(F+) ATCC 10798	UV-LED 280 nm	12	25	38				yes	GF = 0.720	[27]
ATCC 15597-B1 method: double agar layer	*E. coli* K12 A/λ(F+) ATCC 10798	UV-LED 300 nm	3.7	11	19				yes	GF = 0.040	[27]
ATCC 23631-B1	*E. coli* ATCC 23631	LP	8	18	28	40			yes		[69]
ATCC 23631-B1	*E. coli* ATCC 23631	LP	*N/A*	*20*					yes	Action spectrum	[79]
ATCC 23631-B1	*E. coli* ATCC 23631	Laser 254 nm	11	22	34	46			yes	Action spectrum	[79]
ATCC 23631 B1	*E. coli* K12 A/λ(F+)	UV-LED 285 nm	15	29	44				yes	GF = 0.544	[237]
ATCC 23631-B1 method: double agar layer	*E. coli* K12 A/λ(F+)	UV-LED 280 nm	19	40	59				yes	GF = 0.720	[151]
ATCC 23631-B1 method: double agar layer	*E. coli* K12 A/λ(F+)	UV-LED 265 nm	11	25	38	52			yes	GF = 1.236	[110]
ATCC 23631-B1 method:	*E. coli* K12 A/λ(F+)	UV-LED 280 nm	12	25	39	53			yes	GF = 0.720	[110]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
double agar layer											
ATCC 23631-B1 method: double agar layer	*E. coli* K12 A/λ(F+)	UV-LED 300 nm	4	12	20	29			yes	GF = 0.040	[110]
ATCC 23631-B1 method: double agar layer	*E. coli* C3000 ATCC 15597	LP			5.5		25		no		[227]
ATCC 23631-B1 method: double agar layer	*E. coli* C3000 ATCC 15597	UV-LED 266 nm			1.6		4.9		no	GF = 1.217	[227]
ATCC 23631-B1 method: double agar layer	*E. coli* C3000 ATCC 15597	UV-LED 279 nm			1.7		5.6		no	GF = 0.758	[227]
Phage	*E. coli* Hfr K12 ATCC 23631	LP	12	23	36	50	66	83	yes		[204]
Phage	*E. coli* K12 A/λ(F+)	LP	10	23	35				yes		[29]
Phage	*E. coli* K12 A/λ(F+)	LP	11	26	40	55			yes		[80]
Reovirus											
3	Mouse L-60	LP?	11	22					yes		[210]
Type 1 Lang strain	N/A	LP	16	36					yes		[126]
Rotavirus											
SA-11	Monkey kidney cell line MA 104	LP	8	15	27	38			yes		[21]
	MA 104 cell line	LP	*20*	*80*	*140*	*200*			no		[238]
SA-11	MA 104 cell line	LP	7	15	25				yes		[97]
SA-11	MA 104 cell line	LP	9	19	26	36	48		yes		[115]
SA-11	MA 104 cell line	LP	7	15	23				yes		[73]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
SA-11 ATCC VR-1565 method: cell culture, assay based on CPE	MA 104 cells ATCC CRL-2378.1	LP	7	15	31 + tailing				yes		[239]
SA-11 ATCC VR-1565 method: RT-qPCR assay	MA 104 cells ATCC CRL-2378.1	LP	29	58	88	117 + tailing			yes		[239]
Human (HRV-Wa)	N/A	LP	16	24	32	40			yes		[156]
SA-11	MA-104 cell line	LP	10	21	32	43	53		yes		[115]
Siphoviridae	*E. coli* C	LP	1.8	3.6	5.7	7.5	9.3		yes		[59]
T1											
	E. coli CN13	LP	*N/A*	*N/A*	*N/A*	*13*			yes		[76]
	E. coli CN13	MP	*N/A*	*N/A*	*N/A*	*19*			yes		[76]
T1UV											
HER 468	*E. coli* CN13 ATCC 700609	LP	N/A	8.3					yes	Action spectrum	[79]
HER 468	*E. coli* CN13 ATCC 700609	Laser 254 nm	4.3	8.5	13	17			yes	Action spectrum	[79]
HER 468	*E. coli* CN13 ATCC 700609	LP	4.6	9.5	14.7	20	26		yes		[75]
T4											
	E. coli	LP	1.1	2.0	3.0	4.0	6.7		yes		[81]
	E. coli	MP	1.1	1.7	2.6	4.0	7		yes		[81]
	E. coli	LP	3.6	8.0	13				yes		[156]
ATCC 11303	N/A	LP	3.7	7.4	11	17	23	29	yes		[218]
Double-stranded DNA method:	*E. coli* ATCC 11303	MP 297 nm	4	6.8	12				yes	GF = 0.070	[135]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
plaque assay											
Double-stranded DNA method: plaque assay	*E. coli* ATCC 11303	MP 310 nm	22	44	77				yes		[135]
T7											
	E. coli	LP	1.7	5.8	11	16	20		yes		[81]
	E. coli	MP	1.3	3.7	8	13	18		yes		[81]
Coliphage	*E. coli* ATCC 11303	LP	2.7	6.0	11				yes		[130]
Coliphage	*E. coli* ATCC 11303	LP	2.7	6.0	11				yes		[130]
Coliphage	*E. coli* ATCC 11303	UV-LED 255 nm	3.1	7.3	15				yes	GF = 1.065	[130]
Coliphage	*E. coli* ATCC 11303	UV-LED 275 nm	3.4	7.5	15	21			yes	GF = 1.250	[130]
ATCC BAA-1025-B2	*E. coli* CN13 ATCC 700609	LP	N/A	3.8					yes	Action spectrum	[79]
ATCC BAA-1025-B2	*E. coli* CN13 ATCC 700609	Laser 254 nm	1.6	3.6	6.6				yes	Action spectrum	[79]
ATCC BAA-1025-B2	*E. coli* BL21	LP	1.3	3.4	6.3	10	14		yes		[75]
T7m											
ATCC 11303-B38	*E. coli* B ATCC 11303	LP	N/A	3.4					yes	Action spectrum	[79]
ATCC 11303-B38	*E. coli* B ATCC 11303	Laser 254 nm	1.7	3.8	6.3	11			yes	Action spectrum	[79]
V$_1$ (Podoviridae)	*E. coli* WG5	LP	3.1	5.9	8.8				yes		[59]

			Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation								
Virus	Host	Lamp Type	1	2	3	4	5	6	Protocol?	Notes	Reference
Zaire ebolavirus Strain Mayinga-76 method: TCID50	VeroE6 cells ATCC CCL-22	LP	23	46					no	Medium: blood platelet concentrate	[189]

[a]Median Tissue Culture Infectious Dose
[b]DNA weighted fluence
[c]Long-Range Quantitative Polymerase Chain Reaction using a 6 kilobase fragment of DNA
[d]Long-Range PCR using a 1.1 kilobase pairs fragment of DNA
[e]Action spectrum weighted fluence
[f]Quantitative PCR
[g]Integrated Cell Culture Quantitative PCR
[h]The water depth was only 2 mm, so the water factor would have been very close to 1.0. Thus, although the protocol corrections were not made, the corrections would have been small
[i]Integrated Cell Culture and Reverse Transcription PCR
[j]Madin-Darby Canine Kidney cells
[k]Multiplicity of Infection
[l]Buffalo Green Monkey Kidney cells

Table A5. Fluences for multiple log reductions for various algae and other microorganisms.

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation							
Microorganism	Lamp Type	1	2	3	4	5	Protocol?	Notes	Reference
Ascaris suum									
Intact eggs from worms	LP	100	328 + tailing				yes		[82]
Decorticated eggs from worms	LP	30					yes		[82]
Candida albicans									
ATCC 10231	LP			31		80	no		[240]
ATCC 18804	LP			27		78	no		[240]
NBRC 1385	Excilamp 222 nm	6.7	13				no	GF = 0.683	[86]
NBRC 1385	LP	14	24				no		[86]
Candida auris									
AR Bank 0381	LP			39		122	no		[240]
AR Bank 0382	LP	21	32	55	90	149	no		[240]
AR Bank 0383	LP			48		132	no		[240]
AR Bank 0384	LP	22	31	57	100	166	no		[240]
AR Bank 0385	LP			59		192	no		[240]
AR Bank 0386	LP			44		111	no		[240]
AR Bank 0387	LP			41		103	no		[240]
AR Bank 0388	LP			43		116	no		[240]

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation							
Microorganism	Lamp Type	1	2	3	4	5	Protocol?	Notes	Reference
AR Bank 0389	LP			48		132	no		[240]
AR Bank 0390	LP			43		126	no		[240]
Cryptococcus carnescens yeast PYCC 5988	LP	18	32				yes		[241]
***Candida* sp.** New species similar to *C. pomicola* yeast PYCC 5991	LP	<10	25				yes		[241]
Metschnikowia viticola/Candida kofuensis yeast									
PYCC 5993	LP	10	20				yes		[241]
PYCC 5994	LP	8	17				yes		[241]
Metschnikowia viticola/ Candida kofuensis yeast PYCC 5992	LP	10	23				yes		[241]
Microcystis aeruginosa									
PCC7806	LP	*10*	*28*	*>60*			no		[83]
PCC7806	MP	*15*	*130*	*>200*			no		[83]
Microcystis viridis									
	MP	41	95	400			yes		[242]
Penicillium polonicum									
	LP		50				no		[87]
	UV-LED 265 nm	18	33	60	90		yes	GF = 0.941	[88]
	UV-LED 280 nm	9.8	15	22	44		yes	GF = 0.486	[88]
	LP	33	69	95			yes		[88]
	UV-LED 265 nm	19	33	59	94		yes	GF = 0.941	[89]
	UV-LED 280 nm	8.8	15	26	40		yes	GF = 0.486	[89]
	LP	43	80	99			yes		[89]
Rhodosporidium babjevae yeast PYCC 5996	LP	40	90				yes		[241]
Rhodotorula minuta (Saito) yeast PYCC 5990	LP	43	90				yes		[241]
Rhodotorula mucilaginosa yeast									
PYCC 5989	LP	44	81				yes		[241]
PYCC 5995	LP	57	113				yes		[241]
Saccharomyces cerevisiae XS800	LP	42	70	100			no		[243]
Tetraselmis suecica									

		Fluence (UV Dose) (mJ cm^{-2}) for a Given Log Reduction Without Photoreactivation							
Microorganism	Lamp Type	1	2	3	4	5	Protocol?	Notes	Reference
Algae K0297	LP	370	540	720			no		[244]
	MP	33	87	188	314		yes		[242]
Trichoderma harzianum									
	LP		40				no		[87]
	UV-LED 265 nm	8.6	24	37	94		yes	GF = 0.941	[88]
	UV-LED 280 nm	4.6	12	19	35		yes	GF = 0.486	[88]
	LP	25	40	81			yes		[88]
	UV-LED 265 nm	7.6	24	37	91		yes	GF = 0.941	[89]
	UV-LED 280 nm	4	12	26	46		yes	GF = 0.486	[89]
	LP	21	40	81	145		yes		[89]
Trichophyton rubrum									
IFM 64661	Excilamp 222 nm	6.6	20				no	GF = 0.683	[86]
IFM 64661	LP	7.2	16				no		[86]

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