

# Fluence (UV Dose) Required to Achieve Incremental Log Inactivation of Bacteria, Protozoa, Viruses and Algae

*Revised, updated and expanded by*

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## Introduction

### Revision history

This paper represents the second revision of a compilation that goes back to 1999. The original compilation (Wright and Sakamoto 1999) was an internal document of Trojan Technologies. The first revision was published in 2006 (Chevretils et al. 2006). Data from the previous reviews have been included here. In addition, data from the past 10 years have been added and a new table for algae has been added. Two other reviews of the UV sensitivity of microorganisms have been published (Hijnen et al. 2006; Coohill and Sagripanti 2008).

### Brief description and selection criteria for content of the tables

Tables 1-5 (only available in the downloaded magazine version) present a summary of published data on the ultraviolet (UV) fluence-response data for various microorganisms that are pathogens, indicators or organisms encountered in the application, testing of performance, and validation of UV disinfection technologies. The tables reflect the state of knowledge but include the variation in technique and biological response that currently exists in the absence of standardized protocols. Users of the data for their own purposes are advised to exercise critical judgment in how they use the data.

In most cases, the data are 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 (Bolton and Linden 2003; Bolton et al. 2015a) in order to determine the average fluence delivered to the microorganisms within the irradiated sample. 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 are used. In a few cases, filtered polychromatic UV light is used to achieve a narrow band of irradiation around 254 nm. These studies are also designated as LP.

None of the data incorporate any impact of photorepair processes. Only the response to the inactivating fluence is documented. The references from which the data are abstracted must be carefully read to understand how the reported fluences are calculated and what the assumptions and procedures are in the calculations.

It is the intention of the authors and sponsors to keep this table dynamic, with periodic updates. Recommendations for inclusion in the tables, along with the reference source, should be sent to:

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The selection criteria for inclusion are recommended as follows:

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 was used as the UV source, the calculated fluence should usually be determined by using a 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 be 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, enumeration and preparation for experiments;
5. Ideally, as noted above, the protocol published by Bolton and Linden (2003) or the recently published IUVA Protocol (Bolton et al. 2015a) should be followed. In cases where this protocol has not been followed, notes to that effect have been provided. Such data should be considered as an upper limit for the fluence since the normal correction factors have not been applied. In some cases only the water factor has been applied; these are deemed to have met the protocol criterion, since the water factor is the most important correction.
6. 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, excimer lamps, etc.) 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 < 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 (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 Qian et al. 2004, 2005) 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 pre-concentration 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, nutritional state, particle content and a number of other factors can impact on microbe responses to disinfection in real environmental samples or processed water, such real waters should be used for site specific assessments of UV, 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.

These tables can be used as a helpful document for understanding the fluence-responses for different organisms at different 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.

### **Units and nomenclature**

Throughout this review, fluence rate and irradiance (units mW/cm<sup>2</sup>) are used interchangeably since they are virtually identical in a collimated beam apparatus. The term fluence (units mJ/cm<sup>2</sup>) is used, which is the proper term [see Bolton et al. (2015b) 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<sup>2</sup> for irradiance or fluence rate and J/m<sup>2</sup> for fluence (UV dose) are more commonly used. One mW/cm<sup>2</sup> = 10 W/m<sup>2</sup> and 1 mJ/cm<sup>2</sup> = 10 J/m<sup>2</sup>.

### **The tables**

Five tables have been prepared covering spores, bacteria, viruses, algae and other microorganisms. These tables—as well as a reference list—are too large for print, but the full review can be downloaded from the Member Zone on the IUVA website at [www.iuva.org](http://www.iuva.org). ■

**Table 1.** Fluences for multiple log reductions for various spores

| Spore   | Lamp Type                | Fluence (UV dose)<br>(mJ/cm <sup>2</sup> ) for a given log<br>reduction without<br>photoreactivation |     |                   |     |    | Proto-<br>col? | Notes | Reference                  |
|---|--------------------------|--|-----|-------------------|-----|----|----------------|-------|----------------------------|
|   |                          | 1  | 2   | 3                 | 4   | 5  |                |       |                            |
| <b><i>Aspergillus brasiliensis</i></b><br>(previously known as<br><b><i>Aspergillus niger</i></b> ) ATCC<br>16404<br>(dark culture) | LP                       | 122  | 226 | 293               |     |    | yes            |       | Taylor-Edmonds et al. 2015 |
| <b><i>Aspergillus niger</i></b>   |                          |  |     |                   |     |    |                |       |                            |
| ATCC 32625  | LP                       | 116  | 245 | 370               | 560 |    | yes            |       | Clauß 2006                 |
| ATCC 32625  | Excimer<br>222 nm        | 90   | 220 | 325               | 430 |    | yes            |       | Clauß 2006                 |
| <b><i>Bacillus anthracis</i></b>  |                          |  |     |                   |     |    |                |       |                            |
| Sterne  | LP                       | 28   | 37  | 52                |     |    | yes            |       | Nicholson & Galeano 2003   |
| Sterne  | LP                       | 23   | 30  |                   |     |    | yes            |       | Blatchley III et al. 2005  |
| Ames  | LP                       | 25   | ~40 | >120 with tailing |     |    | yes            |       | Rose & O'Connell 2009      |
| 34F2 (Sterne)<br>method: soil extract-<br>peptone-beef extract agar   | LP                       | 23   | ~40 | >120 with tailing |     |    | yes            |       | Rose & O'Connell 2009      |
| 34F2 (Sterne)<br>method: Schaeffer's<br>sporulation medium  | LP                       | 23   | 36  | 80                |     |    | yes            |       | Rose & O'Connell 2009      |
| <b><i>Bacillus atrophaeus</i></b>   |                          |  |     |                   |     |    |                |       |                            |
| ATCC 9372   | LP                       | 22   | 38  | 55                | 71  |    | yes            |       | Zhang et al. 2014          |
|   | LP                       | 10   | 16  | 26                | 39  |    | yes            |       | Sholtes et al. 2016        |
|   | UV-LED<br>260 nm         | 6  | 10  | 14                | 19  | 31 | yes            |       | Sholtes et al. 2016        |
| <b><i>Bacillus cereus</i></b>   |                          |  |     |                   |     |    |                |       |                            |
| ATCC 11778  | Excimer<br>222 nm        | 25   | 43  | 69                |     |    | yes            |       | Clauß 2006                 |
| ATCC 11778  | LP                       | 52   | 93  | 140               |     |    | yes            |       | Clauß 2006                 |
| T   | LP                       | 23   | 30  | 35                | 40  |    | yes            |       | Blatchley III et al. 2005  |
| <b><i>Bacillus megaterium</i></b><br>(spores)<br>QMB 1551   | 265 nm                   | 28   | 42  | 55                |     |    | no             |       | Donnellan & Stafford 1968  |
| <b><i>Bacillus pumilus</i></b>  |                          |  |     |                   |     |    |                |       |                            |
| ASFUVR  | Filtered<br>MP<br>258 nm | 87   | 130 | 184               |     |    | yes            |       | Beck et al. 2015           |
| ASFUVR  | LP                       | 173  | 348 |                   |     |    | yes            |       | Boczek et al. 2016         |
| ATCC 27142  | LP                       | 68   | 138 | 204               | 272 |    | yes            |       | Boczek et al. 2016         |
| <b><i>Bacillus subtilis</i></b>   |                          |  |     |                   |     |    |                |       |                            |
| ATCC 6633   | LP                       | 12   | 18  | 24                | 30  | 36 | yes            |       | Quails & Johnson 1983      |
| ATCC 6633   | LP                       | 36   | 48  | 59                | 77  |    | yes            |       | Chang et al. 1985          |
| ATCC 6633   | LP                       | 28   | 40  | 50                |     |    | yes            |       | Sommer et al. 1998         |
| ATCC 6633   | LP                       | 19   | 40  | 60                | 81  |    | yes            |       | Sommer et al. 1999         |

| Spore                                      | Lamp Type      | Fluence (UV dose)<br>(mJ/cm <sup>2</sup> ) for a given log<br>reduction without<br>photoreactivation |     |     |              |   | Proto-<br>col? | Notes           | Reference                    |
|--|----------------|--|-----|-----|--------------|---|----------------|-----------------|------------------------------|
|  |                | 1  | 2   | 3   | 4            | 5 |                |                 |                              |
| <b><i>Bacillus subtilis</i> (cont.)</b>    |                |  |     |     |              |   |                |                 |                              |
| ATCC 6633                                  | LP             | 31   | 47  | 64  | 80           |   | yes            | Action spectrum | Cabaj et al. 2002            |
| ATCC 6633                                  | LP             | 25   | 39  | 50  | 60           |   | yes            |                 | Nicholson & Galeano 2003     |
| ATCC 6633                                  | LP             | 24   | 35  | 47  | 79           |   | yes            |                 | Mamane-Gravetz & Linden 2004 |
| ATCC 6633 (surface cultured)               | LP             | 11   | 18  | 24  | 31           |   | yes            | Action spectrum | Mamane-Gravetz et al. 2005   |
| ATCC 6633 (liquid cultured)                | LP             | 13   | 23  | 33  |              |   | yes            |                 | Bohrerova et al. 2006        |
| ATCC 6633 (surface cultured)               | LP             | 9  | 15  |     |              |   | yes            |                 | Bohrerova et al. 2006        |
| ATCC 6633 (surface cultured)               | Excimer 222 nm | 7  | 12  | 18  | 23           |   | yes            |                 | Pennell et al. 2008          |
| ATCC 6633 (surface cultured)               | LP             | 19   | 24  | 30  | 35           |   | yes            |                 | Pennell et al. 2008          |
| ATCC 6633 (surface cultured)               | 282 nm         | 19   | 29  | 39  | 49           |   | yes            |                 | Pennell et al. 2008          |
| ATCC 6633                                  | LP             | 9  | 17  | 26  | 34           |   | yes            |                 | Bichae et al. 2009           |
| ATCC 6633                                  | LP             | 21   | 32  | 43  | 55           |   | yes            | Action spectrum | Chen et al. 2009             |
| ATCC 6633 (surface cultured)               | LP             | 18   | 39  | 61  | 82           |   | yes            |                 | Sun & Liu 2009               |
| ATCC 6633                                  | LP             | 24   | 37  | 51  | 80 + tailing |   | yes            |                 | Mamane et al. 2009           |
| ATCC 6633                                  | LP             | 26   | 40  | 55  | 69           |   | yes            |                 | Wang et al. 2010             |
| ATCC 6633                                  | Excimer 222 nm | 13   | 21  | 30  | 38           |   | yes            |                 | Wang et al. 2010             |
| ATCC 6633                                  | Excimer 172 nm | 435  | 869 |     |              |   | yes            |                 | Wang et al. 2010             |
| ATCC 6633                                  | UV-LED 269 nm  | 2  | 10  | 17  | 25           |   | yes            |                 | Würtele et al. 2010          |
| ATCC 6633                                  | UV-LED 282 nm  | 3  | 11  | 18  | 26           |   | yes            |                 | Würtele et al. 2010          |
| ATCC 6051                                  | LP             | 8  | 13  | 17  | 20 + tailing |   | yes            |                 | Jin et al. 2006              |
| TKJ 6312                                   | LP             | 0.7  | 1.5 | 2.3 | 3.7          |   | yes            |                 | Sommer et al. 1999           |
| WN624                                      | LP             | 25   | 36  | 49  | 60           |   | yes            |                 | Nicholson & Galeano 2003     |
| <b><i>Cylindrospermum</i> spores</b>       | LP             | 14   | 26  | 43  |              |   | no             |                 | Singh 1975                   |
| <b><i>Clostridium pasteurianum</i></b>     |                |  |     |     |              |   |                |                 |                              |
| ATCC 6013                                  | LP             | 3.4  | 5.3 | 6.7 | 8.4          |   | yes            |                 | Clauß 2006                   |
| ATCC 6013                                  | Excimer 222 nm | 4.3  | 6.1 | 7.9 | 9.6          |   | yes            |                 | Clauß 2006                   |
| <b><i>Encephalitozoon intestinalis</i></b> |                |  |     |     |              |   |                |                 |                              |
|  | LP             | 2.8  | 5.6 | 8.4 |              |   | yes            |                 | John et al. 2003             |
| (microsporidia)                            | LP & MP        | <3   | 3   | <6  |              |   | yes            |                 | Huffman et al. 2002          |

| Spore                                    | Lamp Type         | Fluence (UV dose)<br>(mJ/cm <sup>2</sup> ) for a given log<br>reduction without<br>photoreactivation |    |     |     |   | Proto-<br>col? | Notes | Reference  |
|--|-------------------|--|----|-----|-----|---|----------------|-------|------------|
|  |                   | 1  | 2  | 3   | 4   | 5 |                |       |            |
| <i>Fischerella muscicola</i><br>spores   | LP                | 189  |    |     |     |   | no             |       | Singh 1975 |
| <b><i>Penicillium expansum</i></b>       |                   |  |    |     |     |   |                |       |            |
| ATCC 36200                               | LP                | 11   | 38 | 49  | 65  |   | yes            |       | Clauß 2006 |
| ATCC 36200                               | Excimer<br>222 nm | 22   | 33 | 42  |     |   | yes            |       | Clauß 2006 |
| <b><i>Streptomyces griseus</i></b>       |                   |  |    |     |     |   |                |       |            |
| ATCC 10137                               | LP                | 8.5  | 13 | 15  | 18  |   | yes            |       | Clauß 2006 |
| ATCC 10137                               | Excimer<br>222 nm | 13   | 17 | 20  | 26  |   | yes            |       | Clauß 2006 |
| <b><i>Thermoactinomyces vulgaris</i></b> |                   |  |    |     |     |   |                |       |            |
| ATCC 43649                               | LP                | 55   | 90 | 115 | 140 |   | yes            |       | Clauß 2006 |
| ATCC 43649                               | Excimer<br>222 nm | 25   | 38 | 46  | 55  |   | yes            |       | Clauß 2006 |

**Table 2.** Fluences for multiple log reductions for various bacteria

| Bacterium   | Lamp Type         | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |     |     |      |     |     | Protocol? | Notes | Reference                 |
|---|-------------------|---|-----|-----|------|-----|-----|-----------|-------|---------------------------|
|   |                   | 1   | 2   | 3   | 4    | 5   | 6   |           |       |                           |
| <i>Aeromonas hydrophila</i><br>ATCC 7966            | LP                | 1.1   | 2.5 | 4.0 | 5.5  | 6.9 | 8.4 | yes       |       | Wilson et al. 1992        |
| <i>Aeromonas salmonicida</i><br>AL 2017             | LP                | 1.5   | 2.7 | 3.1 | 5.9  |     |     | yes       |       | Liltved & Landfald 1996   |
| <b><i>Arthrobacter nicotinovorans</i></b>           |                   |   |     |     |      |     |     |           |       |                           |
| ATCC 49919  | LP                | 8   | 10  | 12  | 14   |     |     | yes       |       | Clauß 2006                |
| ATCC 49919  | Excimer<br>222 nm | 10  | 15  | 18  | 20   |     |     | yes       |       | Clauß 2006                |
| <b><i>Bacillus cereus</i> (veg. bacteria)</b>       |                   |   |     |     |      |     |     |           |       |                           |
| ATCC 11778  | LP                | 6   | 7   | 9   | 12   |     |     | yes       |       | Clauß 2006                |
| ATCC 11778  | Excimer<br>222 nm | 9   | 11  | 14  | 18   |     |     | yes       |       | Clauß 2006                |
| <i>Bacillus megaterium</i><br>(veg. cells) QMB 1551 | 265 nm            | 4.6   |     |     |      |     |     | no        |       | Donnellan & Stafford 1968 |
| <b><i>Burkholderia mallei</i></b>                   |                   |   |     |     |      |     |     |           |       |                           |
| M9  | LP                | 1.0   | 2.4 | 3.8 | 5.2  |     |     | yes       |       | Rose & O'Connell 2009     |
| M13   | LP                | 1.2   | 2.7 | 4.1 | 5.5  |     |     | yes       |       | Rose & O'Connell 2009     |
| <b><i>Brucella melitensis</i></b>                   |                   |   |     |     |      |     |     |           |       |                           |
| ATCC 23456  | LP                | 2.8   | 5.3 | 7.8 | 10.3 |     |     | yes       |       | Rose & O'Connell 2009     |
| IL195   | LP                | 3.7   | 5.8 | 7.8 | 9.9  |     |     | yes       |       | Rose & O'Connell 2009     |
| <b><i>Burkholderia pseudomallei</i></b>             |                   |   |     |     |      |     |     |           |       |                           |
| ATCC 11688  | LP                | 1.7   | 3.5 | 5.5 | 7.4  |     |     | yes       |       | Rose & O'Connell 2009     |
| CA650   | LP                | 1.4   | 2.8 | 4.3 | 5.7  |     |     | yes       |       | Rose & O'Connell 2009     |
| <b><i>Brucella suis</i></b>                         |                   |   |     |     |      |     |     |           |       |                           |
| KS528   | LP                | 2.7   | 5.3 | 7.9 | 10.5 |     |     | yes       |       | Rose & O'Connell 2009     |
| MO 562  | LP                | 1.7   | 3.6 | 5.6 | 7.5  |     |     | yes       |       | Rose & O'Connell 2009     |
| <b><i>Campylobacter jejuni</i></b>                  |                   |   |     |     |      |     |     |           |       |                           |
| ATCC 43429  | LP                | 1.0   | 2.1 | 3.4 | 4.6  | 5.8 |     | yes       |       | Wilson et al. 1992        |
| biotype 1 strain 709/84                             | LP                | 0.8   | 1.3 | 1.7 | 2.1  |     |     | yes       |       | Butler et al. 1987        |
| <i>Citrobacter diversus</i>                         | LP                | 5   | 7   | 9   | 11.5 | 13  |     | yes       |       | Giese & Darby 2000        |
| <i>Citrobacter freundii</i>                         | LP                | 5   | 9   | 13  |      |     |     | yes       |       | Giese & Darby 2000        |
| <i>Corynebacterium diphtheriae</i>                  | LP                | 3.4   |     |     |      |     |     | no        |       | Sharp 1939                |
| <b><i>Deinococcus radiodurans</i></b>               |                   |   |     |     |      |     |     |           |       |                           |
| ATCC 13939  | LP                | 113   | 142 | 170 | 205  |     |     | yes       |       | Clauß 2006                |
| ATCC 13939  | Excimer<br>222 nm | 44  | 57  | 91  |      |     |     | yes       |       | Clauß 2006                |
| <i>Eberthella typhosa</i>                           | LP                | 2.1   |     |     |      |     |     | no        |       | Sharp 1939                |
| <i>Enterococcus faecium</i><br>Vancomycin-resistant | LP                | 7   | 9   | 11  | 13   | 15  |     | yes       |       | McKinney & Pruden 2012    |

| Bacterium                           | Lamp Type      | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |     |              |      |      |     | Protocol? | Notes | Reference                 |
|-------------------------------------|----------------|---|-----|--------------|------|------|-----|-----------|-------|---------------------------|
|                                     |                | 1   | 2   | 3            | 4    | 5    | 6   |           |       |                           |
| <b><i>Enterococcus faecalis</i></b> |                |   |     |              |      |      |     |           |       |                           |
| ATCC27285                           | LP             | 3.7   | 8.0 | 14 + tailing |      |      |     | yes       |       | Moreno-Andrés et al. 2016 |
| DSM 20478                           | LP             | 7.1   | 8.7 | 13 + tailing |      |      |     | yes       |       | Chen et al. 2015          |
| DSM 20478                           | MP             | 5.5   | 7.6 | 12 + tailing |      |      |     | yes       |       | Chen et al. 2015          |
| <b><i>Escherichia coli</i></b>      |                |   |     |              |      |      |     |           |       |                           |
| ATCC 11229                          | LP             | 3.0   | 4.8 | 6.7          | 8.4  | 10.5 |     | yes       |       | Chang et al. 1985         |
| ATCC 11229                          | LP             | 2.5   | 3.0 | 3.5          | 5    | 10   | 15  | yes       |       | Harris et al. 1987        |
| ATCC 11229                          | LP             | 7   | 8   | 9            | 11   | 12   |     | no        |       | Hoyer 1998                |
| ATCC 11229                          | LP             | 3.4   | 5.0 | 6.7          | 8.3  | 10   |     | yes       |       | Sommer et al. 1998        |
| ATCC 11229                          | LP             | 3.5   | 4.7 | 5.5          | 6.5  | 7.5  | 9.6 | yes       |       | Sommer et al. 2000        |
| ATCC 11229                          | LP             | 2.5   | 3.0 | 3.5          | 4.5  | 5.0  | 6.0 | yes       |       | Sommer et al. 2001        |
| ATCC 11229                          | LP             | 3.9   | 5.4 | 6.8          | 8.2  | 9.7  |     | yes       |       | Zimmer & Slawson 2002     |
| ATCC 11229                          | LP             | 3.3   | 4.9 | 5.7          | 6.6  |      |     | yes       |       | Clauß et al. 2005         |
| ATCC 11229                          | Excimer 222 nm | 4.9   | 7.7 | 9.1          | 10.3 |      |     | yes       |       | Clauß et al. 2005         |
| ATCC 11229                          | LP or MP       | 1.6   | 3.0 | 5.0          | 6.5  |      |     | yes       |       | Bohrerova et al. 2008     |
| ATCC 11229                          | LP             | 4.7   | 6.2 | 7.2          | 8.3  | 9.3  |     | yes       |       | Quek & Hu 2008            |
| ATCC 11229                          | MP             | 2.5   | 4.0 | 4.7          | 5.3  | 6.0  | 7.3 | yes       |       | Quek & Hu 2008            |
| ATCC 11229                          | LP             | 4.1   | 5.1 | 6.2          |      |      |     | yes       |       | Bowker et al. 2011        |
| ATCC 11229                          | UV-LED 255 nm  | 5.9   | 7.9 |              |      |      |     | yes       |       | Bowker et al. 2011        |
| ATCC 11229                          | UV-LED 275 nm  | 4.3   | 6.2 | 7.7          |      |      |     | yes       |       | Bowker et al. 2011        |
| ATCC 11303                          | LP             | 4   | 6   | 9            | 10   | 13   | 15  | yes       |       | Wu et al. 2005            |
| ATCC 11775                          | LP             | 1.1   | 2.0 | 3.0          | 3.4  | 4.0  |     | yes       |       | Quek & Hu 2008            |
| ATCC 11775                          | MP             | 0.9   | 1.6 | 2.4          | 3.0  | 3.4  |     | yes       |       | Quek & Hu 2008            |
| ATCC 15597                          | LP             | 6.4   | 8.9 | 11           | 12   | 13   |     | yes       |       | Quek & Hu 2008            |
| ATCC 15597                          | MP             | 5.0   | 6.8 | 8.3          | 9.4  | 11   | 12  | yes       |       | Quek & Hu 2008            |
| ATCC 25922                          | LP             | 6.0   | 6.5 | 7.0          | 8.0  | 9    | 10  | yes       |       | Sommer et al. 1998        |
| ATCC 29425                          | LP             | 5.4   | 8.5 | 20           |      |      |     | yes       |       | Chatterley & Linden 2010  |
| ATCC 29425                          | UV-LED 265 nm  | 3.6   | 5.9 | 17           | 20   |      |     | yes       |       | Chatterley & Linden 2010  |
| ATCC 700891                         | LP             | 7.3   | 10  | 12           | 13   | 15   |     | yes       |       | Quek & Hu 2008            |
| ATCC 700891                         | MP             | 4.8   | 6.8 | 8.2          | 9.0  | 9.8  |     | yes       |       | Quek & Hu 2008            |
| B                                   | LP             | 1.0   | 2.4 | 4.4          | 6    |      |     | yes       |       | Shin et al. 2008          |
| B                                   | MP             | 0.9   | 2.1 | 4.2          | 6    |      |     | yes       |       | Shin et al. 2008          |
| B ATCC 13033                        | LP             | 1.2   | 3.0 | 4.7          | 6.5  | 8.2  | 10  | yes       |       | Sholtes et al. 2016       |
| B ATCC 13033                        | UV-LED 260 nm  | 1.2   | 3.0 | 4.7          | 6.5  | 8.2  | 10  | yes       |       | Sholtes et al. 2016       |
| C                                   | LP             | 2   | 3   | 4            | 5.6  | 6.5  | 8   | yes       |       | Otaki et al. 2003         |



| Bacterium                              | Lamp Type             | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |     |      |      |     |     | Protocol? | Notes | Reference              |
|--|-----------------------|---|-----|------|------|-----|-----|-----------|-------|------------------------|
|  |                       | 1   | 2   | 3    | 4    | 5   | 6   |           |       |                        |
| <b><i>Escherichia coli</i> (cont.)</b> |                       |   |     |      |      |     |     |           |       |                        |
| C3000                                  | LP or MP              | 3.0   | 4.3 | 5.5  | 7.0  |     |     | yes       |       | Eischeid & Linden 2007 |
| CGMCC 1.3373                           | LP                    | 3.1   | 5.9 | 8.0  | 13   |     |     | yes       |       | Guo et al. 2009        |
| CGMCC 1.3373                           | MP                    | 3.1   | 5.9 | 9.6  | 13   |     |     | yes       |       | Guo et al. 2009        |
| CN13                                   | XeBr Exci-lamp 282 nm | 5.5   | 7.5 | 9.6  | 12   |     |     |           |       | Matafonova et al. 2012 |
| K12                                    | LP                    | 1.1   | 1.9 | 2.6  | 3.4  |     |     | no        |       | Qiu et al. 2004        |
| K12 IFO 3301                           | LP & MP               | 2   | 4   | 6    | 7    | 9   |     | yes       |       | Oguma et al. 2002      |
| K12 IFO 3301                           | LP                    | 1.5   | 2.0 | 3.5  | 4.2  | 5.5 | 6.2 | yes       |       | Otaki et al. 2003      |
| K12 IFO 3301                           | LP & MP               | 2.2   | 4.4 | 6.7  | 8.9  | 11  |     | yes       |       | Oguma et al. 2004      |
| K12 IFO 3301                           | UV-LED 265 nm         | 2.6   | 4.7 | 6.6  | 9.0  | 12  |     | yes       |       | Oguma et al. 2013      |
| K12 IFO 3301                           | UV-LED 280nm          | 3.4   | 6.9 | 10   | 14   |     |     | yes       |       | Oguma et al. 2013      |
| K12 IFO 3301                           | LP                    | 1.9   | 4   | 6    | 8    |     |     | yes       |       | Rattanakul et al. 2014 |
| K12 IFO 3301                           | UV-LED 285 nm         | 7.8   | 13  | 16   | 23   | 34  |     | yes       |       | Oguma et al. 2015      |
| K12 IFO 3301                           | LP                    | 2   | 4   | 6    |      |     |     | yes       |       | Oguma et al. 2001      |
| NBIMB 9481                             | LP                    | 5.9   | 8.0 | 9.3  | 10.5 | 12  |     | yes       |       | Quek & Hu 2008         |
| NBIMB 9481                             | MP                    | 4.3   | 6.2 | 7.3  | 8.6  |     |     | yes       |       | Quek & Hu 2008         |
| NBIMB 10083                            | LP                    | 2.8   | 4.4 | 5.6  | 6.6  | 7.6 |     | yes       |       | Quek & Hu 2008         |
| NBIMB 10083                            | MP                    | 2.5   | 4.3 | 5.1  | 6.0  | 6.8 | 7.6 | yes       |       | Quek & Hu 2008         |
| OP50                                   | LP                    | 2.0   | 4.4 | 6.7  | 9.1  |     |     | yes       |       | Bichai et al. 2009     |
| O157: H7                               | LP                    | 1.5   | 3.0 | 4.5  | 6.0  |     |     | no        |       | Tosa & Hirata 1999     |
| O157: H7                               | LP                    | <2  | <2  | 2.5  | 4    | 8   | 17  | ??        |       | Yaun et al. 2003       |
| O157: H7 ATCC 43894                    | LP                    | 1.4   | 2.8 | 4.2  | 5.5  | 6.9 |     | yes       |       | Wilson et al. 1992     |
| O157: H7 CCUG 29193                    | LP                    | 3.5   | 4.7 | 5.5  | 7    |     |     | yes       |       | Sommer et al. 2000     |
| O157: H7 CCUG 29197                    | LP                    | 2.5   | 3.0 | 4.6  | 5.0  | 5.5 |     | yes       |       | Sommer et al. 2000     |
| O157: H7 CCUG 29199                    | LP                    | 0.4   | 0.7 | 1.0  | 1.1  | 1.3 | 1.4 | yes       |       | Sommer et al. 2000     |
| O25: K98: NM                           | LP                    | 5.0   | 7.5 | 9    | 10   | 12  |     | yes       |       | Sommer et al. 2000     |
| O26                                    | LP                    | 5.4   | 8.0 | 10.5 | 12.8 |     |     | no        |       | Tosa & Hirata 1999     |
| O50: H7                                | LP                    | 2.5   | 3.0 | 3.5  | 4.5  | 5   | 6   | yes       |       | Sommer et al. 2000     |
| O78: H11                               | LP                    | 4   | 5   | 5.5  | 6    | 7   |     | yes       |       | Sommer et al. 2000     |
| 145 Ampicillin resistant               | LP                    | 0.8   | 1.9 | 3.0  | 4.7  |     |     | yes       |       | Templeton et al. 2009  |
| 018 Trimethoprim resistant             | LP                    | 1.5   | 3.0 | 4.0  | 4.9  |     |     | yes       |       | Templeton et al. 2009  |
| SMS-3-5                                | LP                    | 3   | 5.1 | 6.5  | 7.6  |     |     | yes       |       | McKinney & Pruden 2012 |
| wild type                              | LP                    | 2.7   | 4.0 | 5.3  | 6.6  |     |     | yes       |       | Butler et al. 1987     |
| wild type                              | LP                    | 4.4   | 6.2 | 7.3  | 8.1  | 9.2 |     | yes       |       | Sommer et al. 2000     |
|  | LP                    | 2.0   | 3.6 | 5.2  | 6.8  |     |     | yes       |       | Hu et al. 2012         |

| Bacterium                                    | Lamp Type | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |     |     |     |     |     | Protocol? | Notes | Reference                 |
|--|-----------|---|-----|-----|-----|-----|-----|-----------|-------|---------------------------|
|  |           | 1   | 2   | 3   | 4   | 5   | 6   |           |       |                           |
| <i>Faecal coliforms</i>                      | LP        | 6   | 9   | 13  | 22  |     |     | yes       |       | Maya et al. 2003          |
| <b><i>Francisella tularensis</i></b>         |           |   |     |     |     |     |     |           |       |                           |
| LVS  | LP        | 1.3   | 3.1 | 4.8 | 6.6 |     |     | yes       |       | Rose & O'Connell 2009     |
| NY98   | LP        | 1.4   | 3.8 | 6.3 | 8.7 |     |     | yes       |       | Rose & O'Connell 2009     |
| <i>Faecal streptococci</i>                   | LP        | 9   | 14  | 22  | 30  |     |     | yes       |       | Maya et al. 2003          |
| <i>Halobacterium elongata</i><br>ATCC 33173  | LP        | 0.4   | 0.7 | 1.0 |     |     |     | no        |       | Martin et al. 2000        |
| <i>Halobacterium salinarum</i><br>ATCC 43214 | LP        | 12  | 15  | 18  | 20  |     |     | no        |       | Martin et al. 2000        |
| <b><i>Helicobacter pylori</i></b>            |           |   |     |     |     |     |     |           |       |                           |
| Texas isolate                                | LP        | 2.2   | 3.0 | 3.8 | 4.6 | 5.7 | 6.6 | yes       |       | Hayes et al. 2006         |
| ATCC 43504                                   | LP        | 4.5   | 5.7 | 6.7 | 7.5 | 8.0 |     | yes       |       | Hayes et al. 2006         |
| ATCC 49503                                   | LP        | 1.7   | 3.1 | 4.0 | 5.3 | 7   |     | yes       |       | Hayes et al. 2006         |
| <i>Klebsiella pneumoniae</i>                 | LP        | 5   | 7   | 10  | 12  |     |     | yes       |       | Giese & Darby 2000        |
| <i>Klebsiella terrigena</i><br>ATCC 33257    | LP        | 3.6   | 6.4 | 9.3 | 12  | 15  |     | yes       |       | Wilson et al. 1992        |
| <i>Legionella longbeachae</i><br>ATCC 33462  | LP        | 1.4   | 3.0 | 4.7 | 6.3 |     |     | yes       |       | Cervero-Arago et al. 2014 |
| <b><i>Legionella pneumophila</i></b>         |           |   |     |     |     |     |     |           |       |                           |
| Philadelphia 2                               | LP        | 0.9   | 1.8 | 2.8 | 3.7 |     |     | no        |       | Antopol & Ellner 1979     |
| ATCC 33152                                   | LP        | 1.6   | 3.2 | 4.8 | 6.4 | 8.0 |     | yes       |       | Oguma et al. 2004         |
| ATCC 33152                                   | MP        | 1.9   | 3.8 | 5.8 | 7.7 | 9.6 |     | yes       |       | Oguma et al. 2004         |
| ATCC 33152                                   | LP        | 1.7   | 3.0 | 4.3 | 5.7 |     |     | yes       |       | Cervero-Arago et al. 2014 |
| ATCC 33823                                   | LP        | 1.7   | 3.1 | 4.5 | 5.8 |     |     | yes       |       | Cervero-Arago et al. 2014 |
| ATCC 43660                                   | LP        | 3.0   | 5.0 | 7.2 | 9.3 |     |     | yes       |       | Wilson et al. 1992        |
| Sero group 1                                 | LP        | 1.7   | 2.9 | 4.2 | 5.4 |     |     | yes       |       | Cervero-Arago et al. 2014 |
| Sero group 8                                 | LP        | 1.8   | 3.3 | 4.7 | 6.1 |     |     | yes       |       | Cervero-Arago et al. 2014 |
| <b><i>Leptospira</i></b>                     |           |   |     |     |     |     |     |           |       |                           |
| <i>biflexa</i> serovar patoc<br>Patoc I      | LP        | 2.3   | 3.8 | 5.1 | 6.7 |     |     | no        |       | Stamm and Charon 1988     |
| <i>illini</i> 3055                           | LP        | 2.8   | 3.8 | 4.8 |     |     |     | no        |       | Stamm and Charon 1988     |
| <i>interrogans</i> serovar<br>Pomona Pomona  | LP        | 0.8   | 1.2 | 1.7 |     |     |     | no        |       | Stamm and Charon 1988     |
| <i>Listeria monocytogenes</i>                | LP        | 2.2   | 3.0 | 3.2 | 4.1 | 4.6 |     | no        |       | Collins 1971              |
| <b><i>Mycobacterium avium</i></b>            |           |   |     |     |     |     |     |           |       |                           |
| 33B  | LP        | 5.8   | 8.1 | 10  | 13  |     |     | yes       |       | Hayes et al. 2008         |
| W41  | LP        | 5.7   | 7.9 | 10  | 12  | 15  |     | yes       |       | Hayes et al. 2008         |

| Bacterium                                     | Lamp Type      | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |     |              |     |     |    | Protocol? | Notes | Reference                |
|---|----------------|---|-----|--------------|-----|-----|----|-----------|-------|--------------------------|
|   |                | 1   | 2   | 3            | 4   | 5   | 6  |           |       |                          |
| <b><i>Mycobacterium avium</i> (cont.)</b>     |                |   |     |              |     |     |    |           |       |                          |
| D55A01  | LP             | 6.4   | 9.4 | 12           | 15  |     |    | yes       |       | Hayes et al. 2008        |
| <b><i>Mycobacterium avium hominissuis</i></b> |                |   |     |              |     |     |    |           |       |                          |
| HMC02 (white transparent) (WT)                | LP             | 7.7   | 12  | 17           | 22  |     |    | yes       |       | Shin et al. 2008         |
| HMC02 (white transparent) (WT)                | MP             | 8.1   | 12  | 16           |     |     |    | yes       |       | Shin et al. 2008         |
| HMC02 (white opaque) (WO)                     | LP             | 7.1   | 11  | 17           |     |     |    | yes       |       | Shin et al. 2008         |
| HMC02 (white opaque) (WO)                     | MP             | 6.6   | 11  | 15           | 19  |     |    | yes       |       | Shin et al. 2008         |
| <b><i>Mycobacterium bovis</i></b><br>BCG      | LP             | 2.2   | 4.4 |              |     |     |    | no        |       | Collins 1971             |
| <b><i>Mycobacterium intracellulare</i></b>    |                |   |     |              |     |     |    |           |       |                          |
| B12CC2  | LP             | 7.8   | 11  | 13           | 16  |     |    | yes       |       | Hayes et al. 2008        |
| ATCC 13950                                    | LP             | 7.4   | 11  | 15           | 19  |     |    | yes       |       | Hayes et al. 2008        |
| <b><i>Mycobacterium phlei</i></b>             | LP             | 3.6   |     |              |     |     |    | no        |       | Collins 1971             |
| <b><i>Mycobacterium terrae</i></b>            |                |   |     |              |     |     |    |           |       |                          |
| ATCC 15755                                    | LP             | 3.9   | 9.3 | 16 + tailing |     |     |    | yes       | (1)   | Bohrerova & Linden 2006a |
| ATCC 15755                                    | LP             | 3.7   | 9.3 | 16           |     |     |    | yes       |       | Bohrerova & Linden 2006b |
| ATCC 15755                                    | MP             | 3.2   | 11  | 39           |     |     |    | yes       |       | Bohrerova & Linden 2006b |
| <b><i>Mycobacterium tuberculosis</i></b>      | LP             | 2.2   | 4.3 |              |     |     |    | no        |       | Collins 1971             |
| <b><i>Pseudomonas aeruginosa</i></b>          |                |   |     |              |     |     |    |           |       |                          |
| ATCC 9027                                     | LP             | 3.8   | 6.5 | 10           | 17  |     |    | no        |       | Abshire & Dunton 1981    |
| ATCC 10145                                    | LP             | 4.6   |     |              |     |     |    | no        |       | Abshire & Dunton 1981    |
| ATCC 14207                                    | LP             | 3.7   |     |              |     |     |    | no        |       | Abshire & Dunton 1981    |
| ATCC 15442                                    | LP             | 3.8   |     |              |     |     |    | no        |       | Abshire & Dunton 1981    |
| ATCC 27853                                    | LP             | 4.9   |     |              |     |     |    | no        |       | Abshire & Dunton 1981    |
| ATCC 27853                                    | LP             | 0.8   | 1.6 | 2.3          | 3.1 |     |    | yes       |       | Clauß 2006               |
| ATCC 27853                                    | Excimer 222 nm | 3.1   | 4.8 | 5.9          | 7.5 | 10  |    | yes       |       | Clauß 2006               |
| 01  | LP             | 1.3   | 2.7 | 4.3          | 6.3 | 10  |    | yes       |       | McKinney & Pruden 2012   |
| B2  | LP             | 5.6   |     |              |     |     |    | no        |       | Abshire & Dunton 1981    |
| G2  | LP             | 3.0   |     |              |     |     |    | no        |       | Abshire & Dunton 1981    |
| BS4   | LP             | 3.5   |     |              |     |     |    | no        |       | Abshire & Dunton 1981    |
| WB1   | LP             | 5.8   |     |              |     |     |    | no        |       | Abshire & Dunton 1981    |
| SH-2918                                       | LP             | 3.5   |     |              |     |     |    | no        |       | Abshire & Dunton 1981    |
| NCTC 10662                                    | LP             | 1.5   | 2.6 | 3.8          | 5.0 | 6.2 |    | yes       |       | Blatchley et al. 2016    |
| <b><i>Salmonella spp.</i></b>                 | LP             | <2  | 2   | 3.5          | 7   | 14  | 29 | ??        |       | Yaun et al. 2003         |

| Bacterium                                       | Lamp Type      | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |     |     |      |     |     | Protocol? | Notes           | Reference                  |
|---|----------------|---|-----|-----|------|-----|-----|-----------|-----------------|----------------------------|
|   |                | 1   | 2   | 3   | 4    | 5   | 6   |           |                 |                            |
| <b><i>Salmonella typhimurium</i></b>            |                |   |     |     |      |     |     |           |                 |                            |
| ATCC 6539                                       | LP             | 2.6   | 4.5 | 5.8 | 7    | 8   |     | yes       |                 | Chang et al. 1985          |
| ATCC 19430                                      | LP             | 2.0   | 4.1 | 6.2 | 8.3  |     |     | yes       |                 | Wilson et al. 1992         |
| (in act. sluge)                                 | LP             | 3   | 12  | 22  | 50   |     |     | yes       |                 | Maya et al. 2003           |
| LT2 SL3770                                      | LP             | 4   | 5.7 | 7.8 |      |     |     | yes       | Action spectrum | Chen et al. 2009           |
|   | LP             | 3.9   | 5.3 | 6.7 | 7.7  | 13  |     | yes       |                 | Hu et al. 2012             |
| <b><i>Serratia marcescens</i></b>               | LP             | 2.2   |     |     |      |     |     | no        |                 | Sharp 1939                 |
| <b><i>Shewanella algae</i></b>                  | LP             | 0.9   | 1.7 | 2.4 | 3.2  |     |     | no        |                 | Qiu et al. 2004            |
| <b><i>Shewanella oneidensis</i></b>             |                |   |     |     |      |     |     |           |                 |                            |
| DLM7  | LP             | 0.3   | 0.5 | 0.8 | 1.1  |     |     | no        |                 | Qiu et al. 2004            |
| MR4   | LP             | 0.7   | 1.4 | 2.1 | 2.8  |     |     | no        |                 | Qiu et al. 2004            |
| MR1   | LP             | 0.2   | 0.4 | 0.6 | 0.9  |     |     | no        |                 | Qiu et al. 2004            |
| <b><i>Shewanella putrefaciens</i> 200</b>       | LP             | 0.5   | 0.8 | 1.1 | 1.4  |     |     | no        |                 | Qiu et al. 2004            |
| <b><i>Shigella dysenteriae</i></b>              |                |   |     |     |      |     |     |           |                 |                            |
| ATCC 29027                                      | LP             | 0.1   | 1.0 | 1.9 | 2.8  | 3.8 | 4.7 | yes       |                 | Wilson et al. 1992         |
|   | LP             | 0.5   | 1.1 | 1.9 | 2.5  | 3.1 |     | yes       |                 | Hu et al. 2012             |
| <b><i>Shigella paradysenteriae</i></b>          | LP             | 1.7   |     |     |      |     |     | no        |                 | Sharp 1939                 |
| <b><i>Shigella sonnei</i></b>                   |                |   |     |     |      |     |     |           |                 |                            |
| ATCC 9290                                       | LP             | 3.2   | 4.9 | 6.5 | 8.2  |     |     | yes       |                 | Chang et al. 1985          |
| <b><i>Staphylococcus albus</i></b>              |                |   |     |     |      |     |     |           |                 |                            |
|   | LP             | 1.8   |     |     |      |     |     | no        |                 | Sharp 1939                 |
|   | LP             | 1.1   | 3.2 | 4.0 | 4.8  |     |     | no        |                 | Collins 1971               |
| <b><i>Staphylococcus aureus</i></b>             |                |   |     |     |      |     |     |           |                 |                            |
|   | LP             | 2.1   | 3.2 |     |      |     |     | no        | Action spectrum | Gates 1929                 |
| (hem)   | LP             | 2.6   |     |     |      |     |     | no        |                 | Sharp 1939                 |
| ATCC 25923                                      | LP             | 3.9   | 5.4 | 6.5 | 10   |     |     | yes       |                 | Chang et al. 1985          |
| ATCC 25923                                      | LP             | 4.4   | 5.8 | 6.4 | 7.3  | 9   |     | yes       |                 | Clauß 2006                 |
| ATCC 25923                                      | Excimer 222 nm | 9.3   | 12  | 14  | 18   |     |     | yes       |                 | Clauß 2006                 |
| ATCC BAA-1556 (Methicillin resistant)           | LP             | 4.5   | 7.2 | 8.8 | 10   |     |     | yes       |                 | McKinney & Pruden 2012     |
| <b><i>Streptococcus faecalis</i> ATCC 29212</b> | LP             | 6.6   | 8.6 | 9.8 | 11.1 |     |     | yes       |                 | Chang et al. 1985          |
| <b><i>Streptococcus hemolyticus</i></b>         | LP             | 2.2   |     |     |      |     |     | no        |                 | Sharp 1939                 |
| <b><i>Vibrio anguillarum</i></b>                | LP             | 0.5   | 1.2 | 1.5 | 2.0  |     |     | yes       |                 | Liltved & Landfald 1996    |
| <b><i>Vibrio cholerae</i></b>                   |                |   |     |     |      |     |     |           |                 |                            |
| Classical OGAWA 154                             | LP             | 0.8   | 1.4 | 2.3 | 3.9  | 6.8 |     | no        |                 | Banerjee & Chatterjee 1977 |

| Bacterium                                  | Lamp Type      | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |     |     |     |     |    | Protocol? | Notes | Reference                  |
|--|----------------|---|-----|-----|-----|-----|----|-----------|-------|----------------------------|
|  |                | 1   | 2   | 3   | 4   | 5   | 6  |           |       |                            |
| <b><i>Vibrio cholerae</i> (cont.)</b>      |                |   |     |     |     |     |    |           |       |                            |
| el tor MAK 154                             | LP             | 1.7   | 4.1 | 7.1 |     |     |    | no        |       | Banerjee & Chatterjee 1977 |
| NAG 1976                                   | LP             | 2.5   | 8.9 |     |     |     |    | no        |       | Banerjee & Chatterjee 1977 |
| ATCC 25872                                 | LP             | 0.7   | 1.4 | 2.1 | 2.8 | 3.6 |    | yes       |       | Wilson et al. 1992         |
| <b><i>Vibrio parahaemolyticus</i> 2977</b> | LP             | 4.4   |     |     |     |     |    | no        |       | Banerjee & Chatterjee 1977 |
| <b><i>Yersinia enterocolitica</i></b>      |                |   |     |     |     |     |    |           |       |                            |
| Sero-group 0:3 strain 304/84               | LP             | 1.2   | 2.2 | 3.0 | 3.6 |     |    | yes       |       | Butler et al. 1987         |
| ATCC 4780                                  | LP             | 2.1   | 4.1 | 5.0 | 5.8 |     |    | yes       |       | Clauß et al. 2005          |
| ATCC 4780                                  | Excimer 222 nm | 3.1   | 6.1 | 7.6 | 8.8 | 10  | 12 | yes       |       | Clauß et al. 2005          |
| ATCC 27729                                 | LP             | 1.6   | 2.7 | 4.0 | 5.1 |     |    | yes       |       | Wilson et al. 1992         |
| <b><i>Yersinia pestis</i></b>              |                |   |     |     |     |     |    |           |       |                            |
| A1122                                      | LP             | 1.4   | 2.6 | 3.7 | 4.9 |     |    | yes       |       | Rose & O'Connell 2009      |
| Harbin                                     | LP             | 1.3   | 2.2 | 3.2 | 4.1 |     |    | yes       |       | Rose & O'Connell 2009      |
| <b><i>Yersinia ruckeri</i></b>             | LP             | 1   | 2   | 3   | 4   |     |    | yes       |       | Liltved & Landfald 1996    |

**Table 3.** Fluences for multiple log reductions for various protozoa

| Protozoan   | Lamp Type  | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |     |     |     |   | Proto-col? | Notes | Reference                                  |
|---|------------|---|-----|-----|-----|---|------------|-------|--|
|   |            | 1   | 2   | 3   | 4   | 5 |            |       |  |
| <b><i>Acanthamoeba castellanii</i></b>  |            |   |     |     |     |   |            |       |  |
| ATCC 30234<br>(life stage: trophozoites;<br>plaque assay)   | LP         | 40  |     |     |     |   | yes        |       | Chang et al. 1985                          |
| CCAP 15342<br>(life stage: trophozoites;<br>method: MPN)  | LP         | 32  | 52  | 72  |     |   | yes        |       | Cervero-Arago et al. 2014                  |
| CCAP 15342<br>(life stage: cysts;<br>method: MPN)   | LP         | 45  | 75  | 91  | 125 |   | yes        |       | Cervero-Arago et al. 2014                  |
| <b><i>Acanthamoeba culbertsoni</i></b><br>ATCC 30171<br>(mouse infectivity assay;<br><i>Mus musculus</i> species,<br>strain CD-1) | LP         | 38  | 58  | 125 | 148 |   | yes        |       | Maya et al. 2003                           |
| <b><i>Acanthamoeba spp.</i></b>   |            |   |     |     |     |   |            |       |  |
| isolated strain<br>(life stage: trophozoites;<br>mouse infectivity assay;<br><i>Mus musculus</i> species,<br>strain CD-1)         | LP         | 39  | 75  | 132 | 160 |   | yes        |       | Maya et al. 2003                           |
| 155<br>(life stage: trophozoites;<br>method: MPN)   | LP         | 28  | 31  | 66  | 71  |   | yes        |       | Cervero-Arago et al. 2014                  |
| 155<br>(life stage: cysts;<br>method: MPN)  | LP         | 34  | 67  | 99  |     |   | yes        |       | Cervero-Arago et al. 2014                  |
| <b><i>Cryptosporidium Hominis</i></b><br>[cell culture infectivity<br>assay using HCT-8 cells<br>(CCL-244) & MDBK<br>cells]       | LP &<br>MP | 3.0   | 5.8 |     |     |   | yes        |       | Johnson et al. 2005                        |
| <b><i>Cryptosporidium parvum</i></b>  |            |   |     |     |     |   |            |       |  |
| [mouse infectivity assay<br>(neonatal CD-1 mice)]   | MP         | <3  | <3  | <3  | 19  |   | yes        |       | Bolton et al. 1998;<br>Bukhari et al. 1999 |
| [mouse infectivity assay<br>(neonatal CD-1 mice)]   | LP         | <3  | <3  | 3-6 | >16 |   | yes        |       | Clancy et al. 2000                         |
| [mouse infectivity assay<br>(neonatal CD-1 mice)]   | MP         | <3  | <3  | 3-9 | >11 |   | yes        |       | Clancy et al. 2000                         |
| [mouse infectivity assay<br>(neonatal CD-1 mice)]   | LP &<br>MP | 2.4   | <5  | 5.2 | 9.5 |   | yes        |       | Craik et al. 2001                          |

| Protozoan  | Lamp Type    | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |      |              |      |     | Protocol? | Notes           | Reference               |
|--|--------------|---|------|--------------|------|-----|-----------|-----------------|-------------------------|
|  |              | 1   | 2    | 3            | 4    | 5   |           |                 |                         |
| <b><i>Cryptosporidium parvum</i> (cont.)</b>   |              |   |      |              |      |     |           |                 |                         |
| [mouse infectivity assay & cell culture infectivity assay using MDCK cells (CCL-34)] | LP           | 1   | 2    | >5           |      |     | yes       |                 | Shin et al. 2001        |
| [mouse infectivity assay (neonatal CD-1 mice)]                                       | MP           | <10   | <10  | >10          |      |     | yes       |                 | Belosevic et al. 2001   |
| [mouse infectivity assay (SCID mice)]  | LP           | 0.5   | 1.0  | 1.4          | 2.2  |     | no        |                 | Morita et al. 2002      |
| [cell culture infectivity assay using HCT-8 cells (CCL-244)]                         | LP           | 2   | <3   | <3           |      |     | yes       |                 | Zimmer et al. 2003      |
| [cell culture infectivity assay using HCT-8 cells (CCL-244)]                         | MP           | <1  | <1   | <1           |      |     | yes       |                 | Zimmer et al. 2003      |
| [culture-immunofluorescence (CC-IFA) based infectivity assay]                        | MP           | 1   | 2    | 2.9          | 4    |     | yes       |                 | Bukhari et al. 2004     |
| [mouse infectivity assay (neonatal CD-1 mice)]                                       | LP           | <2  | <2   | <2           | <4   | <10 | yes       |                 | Clancy et al. 2004      |
| [mouse infectivity assay (neonatal CD-1 mice)]                                       | MP           | <5  | <5   | <5           | ~6   |     | yes       |                 | Amoah et al. 2005       |
| [cell culture infectivity assay using HCT-8 cells (CCL-244)]                         | LP           | 1.8   | 5.6  | 25           |      |     | yes       |                 | Ryu et al. 2008         |
| HNJ-1 [mouse infectivity assay (SCID mice)]  | LP           | <0.7  | <1.4 | 2.2          |      |     | yes       |                 | Oguma et al. 2001       |
| [cell culture infectivity assay using HCT-8 cells (CCL-244)]                         | Laser 254 nm | 1.3   | 1.9  | 2.3          | 2.8  |     | yes       | Action spectrum | Beck et al. 2015        |
| <b><i>Cryptosporidium spp.</i></b>   | LP & MP      | 0.8   | 1.5  | 3.0          | 6.0  |     | yes       | (2)             | Qian et al. 2004        |
| <b><i>Giardia lamblia</i></b>  |              |   |      |              |      |     |           |                 |                         |
| (excystation assay)  | LP?          | 40  | 180  |              |      |     | no?       |                 | Karanis et al. 1992     |
| (gerbil infectivity assay)   | LP           | <10   | ~10  | 20           |      |     | yes       |                 | Campbell & Wallace 2002 |
| (gerbil infectivity assay)   | LP           | <0.5  | <0.5 | <0.5         | <1   |     | yes       |                 | Linden et al. 2002      |
| (gerbil infectivity assay)   | LP           | <2  | <2   | <4           |      |     | yes       |                 | Mofidi et al. 2002      |
| <b><i>Giardia muris</i></b>  |              |   |      |              |      |     |           |                 |                         |
| (mouse infectivity assay)  | MP           | 1   | 4.5  | 28 + tailing |      |     | yes       |                 | Craik et al. 2000       |
| (mouse infectivity assay)  | MP           | <10   | <10  | <25          | ~60  |     | yes       |                 | Belosevic et al. 2001   |
| (mouse infectivity assay)  | LP           | <2  | <2   | <4           |      |     | yes       |                 | Mofidi et al. 2002      |
| (mouse infectivity assay)  | LP           | <2  | <2   | ~2           | ~2.3 |     | no        |                 | Hayes et al. 2003       |
| (mouse infectivity assay)  | LP           | <5  | <5   | 5            |      |     | yes       |                 | Amoah et al. 2005       |

| Protozoan  | Lamp Type | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |     |     |     |   | Protocol? | Notes | Reference                 |
|--|-----------|---|-----|-----|-----|---|-----------|-------|---------------------------|
|  |           | 1   | 2   | 3   | 4   | 5 |           |       |                           |
| <i>Giardia spp.</i>                                    | LP & MP   | 0.6   | 1.1 | 1.9 | 3.4 |   | yes       | (2)   | Qian et al. 2004          |
| <b><i>Naegleria fowleri</i></b>                        |           |   |     |     |     |   |           |       |                           |
| Cysts (method: MPN)                                    | LP        | 32  | 63  | 104 | 121 |   | yes       |       | Sarkar and Gerba 2012     |
| Trophozoites (method: MPN)                             | LP        | 8   | 13  | 18  | 24  |   | yes       |       | Sarkar and Gerba 2012     |
| <b><i>Toxoplasma gondii</i></b>                        |           |   |     |     |     |   |           |       |                           |
| oocysts [immunofluorescence assay (IFA)]               | LP        | 7.2   | 13  | 17  | 19  |   | yes       |       | Dumètre et al. 2008       |
| [mouse infectivity assay (SCID mice)]                  | LP        | 3.4   | 6.8 | 10  |     |   | yes       |       | Ware et al. 2010          |
| <b><i>Vermamoeba vermiformis</i></b>                   |           |   |     |     |     |   |           |       |                           |
| CCAP 15434 /7A (life stage: trophozoites; method: MPN) | LP        | 11  | 19  | 26  | 34  |   | yes       |       | Cervero-Arago et al. 2014 |
| CCAP 15434/7A (life stage: cysts; method: MPN)         | LP        | 17  | 38  | 54  | 78  |   | yes       |       | Cervero-Arago et al. 2014 |
| 195 (life stage: trophozoites; method: MPN)            | LP        | 10  | 17  | 24  | 32  |   | yes       |       | Cervero-Arago et al. 2014 |
| 195 (life stage: cysts; method: MPN)                   | LP        | 32  | 60  | 76  | 110 |   | yes       |       | Cervero-Arago et al. 2014 |



**Table 4.** Fluences for multiple log reductions for various viruses

| Virus                              | Host                                | Lamp Type             | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |     |     |     |              |     | Protocol? | Notes | Reference                |
|------------------------------------|-------------------------------------|-----------------------|---|-----|-----|-----|--------------|-----|-----------|-------|--------------------------|
|                                    |                                     |                       | 1   | 2   | 3   | 4   | 5            | 6   |           |       |                          |
| <b>Adenovirus</b>                  |                                     |                       |   |     |     |     |              |     |           |       |                          |
| Type 1 method: MPN                 | PLC/ PRF/5 and HeLa cell line       | LP                    | 35  | 69  | 103 | 138 |              |     | yes       |       | Nwachuku et al. 2005     |
| Type 2                             | PLC/ PRF/5                          | LP                    | 40  | 78  | 119 | 160 | 195          | 235 | yes       |       | Gerba et al. 2002        |
| Type 2                             | Human lung cell line                | LP                    | 35  | 55  | 75  | 100 |              |     | yes       |       | Ballester & Malley 2004  |
| Type 2                             | A549 cell line                      | LP                    | 20  | 45  | 80  | 110 |              |     | yes       |       | Shin et al. 2005         |
| Type 2                             | A549 cell line                      | LP                    | ~30   | ~60 |     |     |              |     | yes       |       | Linden et al. 2007       |
| Type 2                             | A549 cell line                      | MP                    | ~10   | ~20 | ~30 | ~40 | ~50          |     | yes       |       | Linden et al. 2007       |
| Type 2                             | A549 cell line                      | MP<br><240 nm blocked | ~15   | ~30 | ~45 | ~60 |              |     | yes       |       | Linden et al. 2007       |
| Type 2                             | A549 cell line                      | LP                    | 8   | 31  | 50  | 80  | 117          |     | yes       |       | Eischeid et al. 2009     |
| Type 2 method: TCID50              | A549 cell line                      | LP                    | 35  | 78  | 126 | 168 |              |     | yes       |       | Linden et al. 2009       |
| Type 2 method: TCID50              | A549 cell line                      | MP                    | 14  | 29  | 44  | 80  | 120          |     | yes       | (3)   | Linden et al. 2009       |
| Type 2 method: cell culture        | HEK293 cells human embryonic kidney | LP                    | 37  | 88  | 120 |     |              |     | yes       |       | Baxter et al. 2007       |
| Type 2 adenoid 6 (VR-846)          | A-549 cell line (CCL-185)           | LP                    | 42  | 83  | 124 | 166 |              |     | yes       |       | Sirikanchana et al. 2008 |
| Type 2                             | A549 cell line                      | MP                    | 4   | 7   | 14  | 22  | 40 + tailing |     | yes       |       | Eischeid et al. 2009     |
| Type 2 method: TCID50              | A549 cell line (CCL-185)            | LP                    | 36  | 82  |     |     |              |     | yes       |       | Shin et al. 2009         |
| Type 2 method: TCID50              | A549 cell line (CCL-185)            | MP                    | 15  | 29  | 45  | 59  | 80           |     | yes       |       | Shin et al. 2009         |
| Type 2 ATCC VR-846; method: TCID50 | A549 cell line (CCL-185)            | LP                    | 56  | 108 | 159 | 206 |              |     | yes       |       | Bounty et al. 2012       |
| Type 2 method: plaque assay        | A549 cell line (CCL-185)            | LP                    | 39  | 71  | 98  | 125 |              |     | yes       |       | Rodriguez et al. 2013    |

|   |                          | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |             |                 |     |     |   |   |           |                 |                       |                       |
|---|--------------------------|---|-------------|-----------------|-----|-----|---|---|-----------|-----------------|-----------------------|-----------------------|
| Virus   | Host                     | Lamp Type   | 1           | 2               | 3   | 4   | 5 | 6 | Protocol? | Notes           | Reference             |                       |
| <b>Adenovirus (cont.)</b>                           |                          |   |             |                 |     |     |   |   |           |                 |                       |                       |
| Type 2 method: plaque assay                         | A549 cell line (CCL-185) | MP  | 7           | 18              | 28  | 47  |   |   | yes       |                 | Rodriguez et al. 2013 |                       |
| Type 2 method: LR-qPCR 6 kb fragment                | A549 cell line (CCL-185) | LP  | 5           | 20-50           | 100 |     |   |   | yes       |                 | Rodriguez et al. 2013 |                       |
| Type 2 method: LR-qPCR 6 kb fragment                | A549 cell line (CCL-185) | MP  | 4           | 15-50           | 100 |     |   |   | yes       |                 | Rodriguez et al. 2013 |                       |
| Type 2 method: LR-qPCR 1 kb fragment                | A549 cell line (CCL-185) | LP  | 18          | 50              | 100 |     |   |   | yes       |                 | Rodriguez et al. 2013 |                       |
| Type 2 method: LR-qPCR 1 kb fragment                | A549 cell line (CCL-185) | MP  | 5 + tailing |                 |     |     |   |   |           | yes             |                       | Rodriguez et al. 2013 |
| Type 2 method: LR-qPCR 10 kb fragment               | A549 cell line (CCL-185) | LP  | 15          |                 |     |     |   |   | yes       |                 | Rodriguez et al. 2013 |                       |
| Type 2 method: LR-qPCR 10 kb fragment               | A549 cell line (CCL-185) | MP  | 39          | 94              |     |     |   |   | yes       |                 | Rodriguez et al. 2013 |                       |
| Type 2 ATCC VR-846 method: MPN                      | A549 cell line (CCL-185) | LP  | 43          | 86              | 130 | 174 |   |   | yes       | Action spectrum | Beck et al. 2014      |                       |
| Type 2 ATCC VR-846; method: LR-PCR 1.1 kbp fragment | A549 cell line (CCL-185) | LP  | 45          | 68              |     |     |   |   | yes       |                 | Beck et al. 2014      |                       |
| 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             |                       | Beck et al. 2014      |
| Type 2 ATCC VR-846 method: MPN                      | A549 cell line (CCL-185) | LP  | 40          | 76              | 120 |     |   |   | yes       |                 | Beck et al. 2014      |                       |

|  |                                      | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |     |     |     |     |     |     |           |       |                        |  |
|--|--------------------------------------|---|-----|-----|-----|-----|-----|-----|-----------|-------|------------------------|--|
| Virus  | Host                                 | Lamp Type   | 1   | 2   | 3   | 4   | 5   | 6   | Protocol? | Notes | Reference              |  |
| <b>Adenovirus (cont.)</b>                    |                                      |   |     |     |     |     |     |     |           |       |                        |  |
| Type 2 ATCC VR-846 method: MPN               | A549 cell line (CCL-185)             | MP  | 8   | 18  | 34  |     |     |     | yes       | (3)   | Beck et al. 2014       |  |
| Type 2 ATCC VR-846 method: MPN               | A549 cell line (CCL-185)             | MP  | 32  | 71  | 135 |     |     |     | yes       | (4)   | Beck et al. 2014       |  |
| Type 2; method: cell culture                 | A549 cell line (CCL-185)             | Laser 254 nm  | 40  | 70  | 101 |     |     |     | yes       |       | Beck et al. 2014       |  |
| Type 2; method: infectivity                  | A549 cell line                       | LP  | 33  | 118 |     |     |     |     | no        |       | Calgua et al. 2014     |  |
| Type 2; method: qPCR                         | A549 cell line                       | LP  | 140 |     |     |     |     |     | no        |       | Calgua et al. 2014     |  |
| Type 2; method: MPN                          | A549 cell line (CCL-185)             | LP  | 47  | 86  | 129 | 172 |     |     | yes       |       | Ryu et al. 2015        |  |
| Type 2; ATCC VR-846; method: ICC-qPCR        | A549 cell line (CCL-185)             | LP  | 40  | 81  | 121 | 161 |     |     | yes       |       | Ryu et al. 2015        |  |
| Type 2; method: total culturable virus assay | A549 cell line (CCL-185)             | LP  | 26  | 100 | 135 | 168 | 203 | 234 | yes       |       | Boczek et al. 2016     |  |
| Type 4; ATCC VR-1572; method: ICC qPCR       | PLC/ PRF/5 ATCC CRL-8024             | LP  | 10  | 34  | 69  | 116 |     |     | yes       |       | Gerrity et al. 2008    |  |
| Type 5; method: cell culture                 | HEK 293 cells human embryonic kidney | LP  | 45  | 76  | 120 |     |     |     | yes       |       | Baxter et al. 2007     |  |
| Type 5                                       | HEK293                               | LP  | 38  | 76  | 114 | 152 |     |     | yes       |       | Guo et al. 2010        |  |
| Type 5                                       | HEK293                               | MP  | 23  | 45  | 68  | 90  |     |     | yes       |       | Guo et al. 2010        |  |
| Type 5                                       | PLC/PRF/5                            | LP  | 31  | 62  | 93  | 123 |     |     | yes       |       | Guo et al. 2010        |  |
| Type 5                                       | PLC/PRF/5                            | MP  | 22  | 43  | 65  | 87  |     |     | yes       |       | Guo et al. 2010        |  |
| Type 5                                       | XP17BE                               | LP  | 13  | 26  | 39  | 52  |     |     | yes       |       | Guo et al. 2010        |  |
| Type 5                                       | XP17BE                               | MP  | 9   | 18  | 27  | 36  |     |     | yes       |       | Guo et al. 2010        |  |
| Type 5                                       | A549 cell line (CCL-185)             | LP  | 51  | 101 | 151 |     |     |     | yes       |       | Rattanakul et al. 2014 |  |

|  |   | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |    |     |     |      |     |     |            |       |                               |
|--|---|---|----|-----|-----|------|-----|-----|------------|-------|-------------------------------|
| Virus                                    | Host  | Lamp Type   | 1  | 2   | 3   | 4    | 5   | 6   | Proto-col? | Notes | Reference                     |
| <b>Adenovirus (cont.)</b>                |   |   |    |     |     |      |     |     |            |       |                               |
| Type 5                                   | A549 cell line (CCL-185)  | LP  | 63 | 100 | 151 |      |     |     | yes        |       | Rattanakul et al. 2015        |
| Type 5 ATCC VR5                          | A549 cell line (CCL-185)  | UV-LED 285 nm   | 50 | 82  | 126 |      |     |     | yes        |       | Oguma et al. 2015             |
| Type 6; method: MPN                      | PLC/ PRF/5 and HeLa cell line                                     | LP  | 39 | 77  | 115 | 154  |     |     | yes        |       | Nwachuku et al. 2005          |
| Type 40; strain: Dugan                   | PLC/PRF5 cell line  | LP  | 50 | 109 | 167 |      |     |     | yes        |       | Thurston-Enriquez et al. 2003 |
| Type 40; method: MPN                     | PLC/PRF5 cell line  | MP  | 16 | 23  | ~30 | ~40  |     |     | yes        |       | Linden et al. 2007            |
| Type 40; method: MPN                     | PLC/PRF5 cell line  | LP  | 63 | 88  | 109 | >120 |     |     | yes        |       | Blatchley et al. 2008         |
| Type 40                                  | HEK293  | LP  | 35 | 70  | 105 | 139  |     |     | yes        |       | Guo et al. 2010               |
| Type 40                                  | HEK293  | MP  | 17 | 33  | 50  | 66   |     |     | yes        |       | Guo et al. 2010               |
| Type 40                                  | PLC/PRF/5   | LP  | 34 | 67  | 101 | 134  |     |     | yes        |       | Guo et al. 2010               |
| Type 40                                  | PLC/PRF/5   | MP  | 16 | 33  | 49  | 65   |     |     | yes        |       | Guo et al. 2010               |
| Type 41; ATCC VR-930; method: ICC-RT-PCR | HEK 293 cells ATCC CRL-1573                                       | LP  | 56 | 111 | 167 | 222  |     |     | yes        |       | Ko et al. 2005                |
| Type 41; method: cell culture            | HEK 293 cells human embryonic kidney & PLC/PRF/5 (heaptoma) cells | LP  | 62 | 120 |     |      |     |     | yes        |       | Baxter et al. 2007            |
| Type 41                                  | HEK293  | LP  | 45 | 91  | 136 | 182  |     |     | yes        |       | Guo et al. 2010               |
| Type 41                                  | HEK293  | MP  | 20 | 39  | 59  | 78   |     |     | yes        |       | Guo et al. 2010               |
| Type 41                                  | PLC/PRF/5   | LP  | 34 | 68  | 103 | 137  |     |     | yes        |       | Guo et al. 2010               |
| Type 41                                  | PLC/PRF/5   | MP  | 18 | 36  | 53  | 71   |     |     | yes        |       | Guo et al. 2010               |
| Type 41                                  | XP17BE  | LP  | 14 | 29  | 43  | 57   |     |     | yes        |       | Guo et al. 2010               |
| Type 41                                  | XP17BE  | MP  | 11 | 21  | 32  | 42   |     |     | yes        |       | Guo et al. 2010               |
| <b>Atlantic halibut nodavirus (AHNV)</b> | SSN-1 cell line   | LP  | 35 | 70  | 104 | 140  | 176 | 211 | yes        |       | Liltved et al. 2006           |
| <b>B40-8 (phage)</b>                     |   |   |    |     |     |      |     |     |            |       |                               |
|  | <i>B. fragilis</i> HSP-40   | LP  | 12 | 18  | 23  | 28   |     |     | yes        |       | Sommer et al. 1998            |
|  | <i>B. fragilis</i>  | LP  | 11 | 17  | 23  | 29   | 35  | 41  | yes        |       | Sommer et al. 2001            |

|  |  |           |     | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |     |     |     |   |            |       |                               |  |  |
|--|--|-----------|-----|---|-----|-----|-----|---|------------|-------|-------------------------------|--|--|
| Virus  | Host   | Lamp Type | 1   | 2   | 3   | 4   | 5   | 6 | Proto-col? | Notes | Reference                     |  |  |
| <b>Calicivirus feline</b>                          |  |           |     |   |     |     |     |   |            |       |                               |  |  |
|  | CRFK cell line   | LP        | 5   | 15  | 23  | 30  | 39  |   | yes        |       | Thurston-Enriquez et al. 2003 |  |  |
|  | MDCK cell line   | LP        | 7   | 15  | 22  | 30  | 36  |   | yes        |       | de Roda Husman et al. 2004    |  |  |
|  | CRFK cell line   | LP        | 7   | 16  | 25  |     |     |   | yes        |       | de Roda Husman et al. 2004    |  |  |
| FCV ATCC VR-782                                    | Crandell Reese feline kidney cell CRfk, ATCC CCL-94    | LP        | 5   | 12  | 18  | 26  |     |   | yes        |       | Park et al. 2011              |  |  |
| <b>Coxsackievirus</b>                              |  |           |     |   |     |     |     |   |            |       |                               |  |  |
| B3   | BGM cell line  | LP        | 8   | 16  | 25  | 33  |     |   | yes        |       | Gerba et al. 2002             |  |  |
| B4   | BGM cell line  | LP        | 7   | 13  | 18  | 24  | 29  |   | yes        |       | Shin et al. 2005              |  |  |
| B5   | BGM cell line  | LP        | 9.5 | 18  | 27  | 36  |     |   | yes        |       | Gerba et al. 2002             |  |  |
| B5   | BGM cell line  | LP        | 7   | 14  | 21  |     |     |   | yes        |       | Battigelli et al. 1993        |  |  |
| <b>Echovirus</b>                                   |  |           |     |   |     |     |     |   |            |       |                               |  |  |
| I  | BGM cell line  | LP        | 8   | 17  | 25  | 33  |     |   | yes        |       | Gerba et al. 2002             |  |  |
| II   | BGM cell line  | LP        | 7   | 14  | 21  | 28  |     |   | yes        |       | Gerba et al. 2002             |  |  |
| 12   | foetal rhesus monkey kidney cell FRhK-4, ATCC CRL-1688 | LP        | 8   | 13  | 18  | 28  | 40  |   | yes        |       | Park et al. 2011              |  |  |
| <b>GA phage</b>                                    | <i>E. coli</i> Hfr K12 ATCC 23631                      | LP        | 18  | 38  | 58  | 87  | 121 |   | yes        |       | Simonet & Gantzer 2006        |  |  |
| <b>Hepatitis</b>                                   |  |           |     |   |     |     |     |   |            |       |                               |  |  |
| A HM175  | FRhK-4 cell  | LP        | 5.4 | 15  | 25  | 35  |     |   | yes        |       | Wilson et al. 1992            |  |  |
| A HM175  | FRhK-4 cell  | LP        | 4   | 8   | 12  | 16  |     |   | yes        |       | Battigelli et al. 1993        |  |  |
| A  | HAV/HFS/GBM  | LP        | 6   | 10  | 15  | 21  |     |   | no         |       | Wiedenmann et al. 1993        |  |  |
| <b>Infectious pancreatic necrosis virus (IPNV)</b> | BF-2 cell line   | LP        | 82  | 165   | 246 | 325 |     |   | yes        |       | Liltved et al. 2006           |  |  |
| <b>Infectious salmon anaemia virus (ISAV)</b>      | SHK-1 cell line  | LP        | 2.5 | 5.0   | 7.5 |     |     |   | yes        |       | Liltved et al. 2006           |  |  |

|                            |                                    |               | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |     |     |     |     |     |           |       |                               |
|----------------------------|------------------------------------|---------------|---|-----|-----|-----|-----|-----|-----------|-------|-------------------------------|
| Virus                      | Host                               | Lamp Type     | 1   | 2   | 3   | 4   | 5   | 6   | Protocol? | Notes | Reference                     |
| <b>JC polyomavirus</b>     |                                    |               |   |     |     |     |     |     |           |       |                               |
| Mad-4 method: cell culture | SVG-A cells                        | LP            | 60  | 124 | 171 |     |     |     | no        |       | Calgua et al. 2014            |
| Mad-4 method: qPCR         | SVG-A cells                        | LP            | >180  |     |     |     |     |     | no        |       | Calgua et al. 2014            |
| <b>MS2 coliphage</b>       |                                    |               |   |     |     |     |     |     |           |       |                               |
|                            | N/A                                | UV-LED 255 nm | 14  | 26  | 38  |     |     |     | yes       |       | Aoyagi et al. 2011            |
|                            | <i>E. coli</i> Famp                | LP            | 13  | 25  | 44  | 64  |     |     | yes       |       | Rodriguez et al. 2014         |
|                            | <i>E. coli</i> Famp                | MP            | 9   | 17  | 31  | 46  | 56  |     | yes       |       | Rodriguez et al. 2014         |
|                            | <i>E. coli</i> Cr63                | LP            | 17  | 34  |     |     |     |     | yes       |       | Rauth 1965                    |
|                            | <i>E. coli</i> C3000               | LP            | 35  |     |     |     |     |     | yes       |       | Battigelli et al. 1993        |
|                            | <i>E. coli</i> ATCC15597           | LP?           | 19  | 40  | 61  |     |     |     | no        |       | Oppenheimer et al. 1993       |
|                            | <i>Salmonella typhimurium</i> WG49 | LP            | 16  | 35  | 57  | 83  | 114 | 152 | no        |       | Nieuwstad & Havelaar 1994     |
|                            | <i>E. coli</i> ATCC15597           | LP            | 13  | 29  | 45  | 62  | 80  |     | yes       |       | Meng & Gerba 1996             |
|                            | <i>E. coli</i> C3000               | LP            | 13  | 28  |     |     |     |     | yes       |       | Shin et al. 2001              |
|                            | <i>E. coli</i> K-12 Hfr            | LP            | 21  | 36  |     |     |     |     | yes       |       | Sommer et al. 1998            |
|                            | <i>E. coli</i> K-12                | LP            | 19  | 36  | 55  |     |     |     | yes       |       | Sommer et al. 2001            |
|                            | <i>E. coli</i> C3000               | LP            | 20  | 42  | 68  | 90  |     |     | yes       |       | Linden et al. 2002            |
|                            | <i>E. coli</i> ATCC 15977          | LP            | 20  | 50  | 85  | 120 |     |     | yes       |       | Thurston-Enriquez et al. 2003 |
|                            | <i>E. coli</i> ATCC 15977          | LP            | 20  | 42  | 70  | 98  | 133 |     | no        |       | Lazarova & Savoye 2004        |
|                            | <i>E. coli</i> C3000               | LP            | 20  | 42  | 69  | 92  |     |     | yes       |       | Batch et al. 2004             |
|                            | <i>E. coli</i> ATCC 15977          | LP            | 29  | 58  | 87  | 116 |     |     | yes       |       | Nwachuku et al. 2005          |
|                            | <i>E. coli</i> ATCC 15977          | LP            | 14  | 33  | 50  | 66  |     |     | yes       |       | Hu et al. 2012                |
|                            | <i>E. coli</i> K12 A/λ(F+)         | LP            | 22  | 48  |     |     |     |     | yes       |       | Rattanakul et al. 2014        |

|                              |                                    |               | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |     |    |     |     |     |           |                 |                            |
|------------------------------|------------------------------------|---------------|---|-----|----|-----|-----|-----|-----------|-----------------|----------------------------|
| Virus                        | Host                               | Lamp Type     | 1   | 2   | 3  | 4   | 5   | 6   | Protocol? | Notes           | Reference                  |
| <b>MS2 coliphage (cont.)</b> |                                    |               |   |     |    |     |     |     |           |                 |                            |
|                              | <i>E. coli</i> Famp ATCC 700891    | LP            | 14  | 30  | 45 | 60  |     |     | yes       |                 | Sholtes et al. 2016        |
|                              | <i>E. coli</i> Famp ATCC 700891    | UV-LED 260 nm | 13  | 36  | 40 | 53  |     |     | yes       |                 | Sholtes et al. 2016        |
| method: cell culture         | <i>Salmonella typhimurium</i> WG49 | LP            | 20  | 40  | 61 | 91  | 119 | 146 | no        |                 | Calgua et al. 2014         |
| method: qPCR                 | <i>Salmonella typhimurium</i> WG49 | LP            | <180  |     |    |     |     |     | no        |                 | Calgua et al. 2014         |
| ATCC15977-B1                 | <i>E. coli</i> ATCC 15977          | LP            | 17  | 38  | 59 | 81  | 103 | 123 | yes       |                 | Wilson et al. 1992         |
| ATCC15977-B1                 | <i>E. coli</i> HS(pFamp)R          | LP            | 16  | 45  | 72 | 100 | 128 | 154 | yes       |                 | Thompson et al. 2003       |
| ATCC15977-B1                 | <i>E. coli</i> ATCC 15977          | LP            | 15  | 32  | 51 | 72  | 98  |     | yes       |                 | Lazarova & Savoye 2004     |
| ATCC15977-B1                 | <i>E. coli</i> ATCC 15977          | LP            | 25  | 42  | 66 | 97  |     |     | yes       |                 | Butkus et al. 2004         |
| ATCC15977-B1                 | <i>E. coli</i> ATCC 15977          | LP            | 20  | 40  | 62 | 92  | 141 | 173 | yes       |                 | Ko et al. 2005             |
| ATCC15977-B1                 | <i>E. coli</i> ATCC 15977          | LP            | 20  | 40  | 62 | 92  | 141 | 173 | yes       |                 | Ko et al. 2005             |
| ATCC15977-B1                 | <i>E. coli</i> ATCC 15977          | LP            | 18  | 38  | 59 | 80  |     |     | yes       |                 | Sun & Liu 2009             |
| ATCC15977-B1                 | <i>E. coli</i> NCTC12486           | LP            | 20  | 40  | 60 |     |     |     | yes       | Action spectrum | Mamane-Gravetz et al. 2005 |
| ATCC15977-B1                 | <i>E. coli</i> Hfr K12 ATCC 23631  | LP            | 20  | 40  | 68 | 95  | 125 |     | yes       |                 | Simonet & Gantzer 2006     |
| ATCC15977-B1                 | <i>E. coli</i> ATCC 15597          | LP            | 18  | 40  |    |     |     |     | yes       |                 | Templeton et al. 2006      |
| ATCC15977-B1                 | <i>E. coli</i> ATCC 15597 C3000    | LP            | 14  | 29  | 45 |     |     |     | yes       |                 | Bohrerova et al. 2006      |
| ATCC15977-B1                 | <i>E. coli</i> Famp                | LP            | 16  | >30 |    |     |     |     | yes       |                 | Lee et al. 2008            |
| ATCC15977-B1                 | <i>E. coli</i> ATCC 15597          | LP            | 20  | 39  | 61 | 83  |     |     | yes       |                 | Blatchley III et al. 2008  |
| ATCC15977-B1                 | <i>E. coli</i> ATCC 15597          | LP            | 18  | 41  |    |     |     |     | yes       |                 | Bowker et al. 2011         |
| ATCC15977-B1                 | <i>E. coli</i> ATCC 15597          | UV-LED 255 nm | 25  | 50  |    |     |     |     | yes       |                 | Bowker et al. 2011         |

|  |                                       | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |    |    |     |    |     |     |           |                 |                      |  |
|--|---------------------------------------|---|----|----|-----|----|-----|-----|-----------|-----------------|----------------------|--|
| Virus  | Host                                  | Lamp Type   | 1  | 2  | 3   | 4  | 5   | 6   | Protocol? | Notes           | Reference            |  |
| <b>MS2 coliphage (cont.)</b>                       |                                       |   |    |    |     |    |     |     |           |                 |                      |  |
| ATCC15977-B1                                       | <i>E. coli</i> ATCC 15597             | UV-LED 275 nm   | 25 | 55 |     |    |     |     | yes       |                 | Bowker et al. 2011   |  |
| ATCC15977-B1                                       | <i>E. coli</i> Famp ATCC 700891       | LP  | 14 | 32 | 51  |    |     |     | yes       |                 | Park et al. 2011     |  |
| ATCC15977-B1                                       | N/A                                   | LP  | 13 | 30 | 53  | 70 |     |     | yes       |                 | Timchak & Gitis 2012 |  |
| ATCC15977-B1                                       | <i>E. coli</i> ATCC 15597 Migula      | LP  | 18 | 52 | 75  | 92 | 106 | 116 | yes       |                 | Guo & Hu 2012        |  |
| ATCC15977-B1                                       | <i>E. coli</i> ATCC 15597             | LP  | 20 | 40 | 70  | 95 | 120 | 138 | no        |                 | Sherchan et al. 2014 |  |
| ATCC15977-B1                                       | <i>E. coli</i> ATCC 15597 C3000       | LP  | 20 | 45 |     |    |     |     | yes       |                 | Jenny et al. 2014    |  |
| ATCC15977-B1                                       | <i>E. coli</i> ATCC 15597 C3000       | UV-LED 260 nm   | 15 | 32 | 48  |    |     |     | yes       |                 | Jenny et al. 2014    |  |
| ATCC15977-B1                                       | <i>E. coli</i> ER2738                 | UV-LED 255 nm   | 19 | 42 | 72  |    |     |     | no        |                 | Simons et al. 2014   |  |
| ATCC15977-B1                                       | <i>E. coli</i> Hfr K12 ATCC23631      | LP  | 6  | 13 | 21  | 29 | 37  | 46  | yes       |                 | Song et al. 2015     |  |
| ATCC15977-B1                                       | <i>E. coli</i> HS(pFamp)R ATCC 700891 | LP  | 18 | 33 | 63  |    |     |     | yes       | Action spectrum | Beck et al. 2015     |  |
| ATCC15977-B1<br>(Action spectrum weighted fluence) | <i>E. coli</i> HS(pFamp)R ATCC 700891 | MP  | 15 | 32 | 52  |    |     |     | yes       | Action spectrum | Beck et al. 2015     |  |
| ATCC15977-B1                                       | <i>E. coli</i> HS(pFamp)R ATCC 700891 | LP  | 20 | 40 | 60  |    |     |     | yes       | Action spectrum | Beck et al. 2016     |  |
| ATCC15977-B1                                       | <i>E. coli</i> K12 A/λ(F+)            | UV-LED 285 nm   | 32 | 70 | 106 |    |     |     | yes       |                 | Oguma et al. 2015    |  |
| ATCC15977-B1                                       | <i>E. coli</i> Famp ATCC 700891       | LP  | 17 | 35 | 60  | 88 | 116 |     | yes       |                 | Boczek et al. 2016   |  |



|                              |                                    | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |     |     |     |      |     |    |            |       |                         |
|------------------------------|------------------------------------|---|-----|-----|-----|------|-----|----|------------|-------|-------------------------|
| Virus                        | Host                               | Lamp Type   | 1   | 2   | 3   | 4    | 5   | 6  | Proto-col? | Notes | Reference               |
| <b>MS2 coliphage (cont.)</b> |                                    |   |     |     |     |      |     |    |            |       |                         |
| F-specific                   | <i>E. coli</i> WG21                | LP  | 8   | 17  | 25  | 33   |     |    | yes        |       | Havelaar et al. 1990    |
| F-specific                   | <i>E. coli</i> WG21                | MP  | 9   | 19  | 28  | 38   |     |    | yes        |       | Havelaar et al. 1990    |
| ATCC15977-B1<br>F-specific   | <i>E. coli</i> C3000               | LP  | 14  | 29  | 49  |      |     |    | yes        |       | Shin et al. 2005        |
| ATCC15977-B1<br>F-specific   | <i>E. coli</i> ATCC 15597<br>C3000 | LP  | 19  | 42  | 69  |      |     |    | yes        |       | Shin et al. 2009        |
| ATCC15977-B1<br>F-specific   | <i>E. coli</i> ATCC 15597<br>C3000 | MP  | 16  | 33  | 53  | 90   |     |    | yes        |       | Shin et al. 2009        |
| DSM5694                      | <i>E. coli</i> NCIB 9481           | LP?   | 4   | 16  | 38  | 68   | 110 |    | no         |       | Wiedenmann et al. 1993  |
| <b>Myoviridae</b>            | <i>E. coli</i> C                   | LP  | 1.8 | 3.6 | 5.1 | 6.7  | 8.5 |    | yes        |       | Shin et al. 2005        |
| <b>Murine norovirus</b>      |                                    |   |     |     |     |      |     |    |            |       |                         |
| NCIMB10108                   | RAW 264.7 cells                    | LP  | 10  | 15  | 22  | 27   | 30  |    | yes        |       | Lee et al. 2008         |
| CW3                          | RAW 264.7 macropags<br>ATCC TIB-71 | LP  | 10  | 15  | 22  | 27   | 30  |    | yes        |       | Park et al. 2011        |
| <b>Phage B124-54</b>         | <i>B. fragilis</i> strain GB-124   | LP  | 14  | 21  | 28  |      |     |    | yes        |       | Diston et al. 2012      |
| <b>PHI X 174</b>             |                                    |   |     |     |     |      |     |    |            |       |                         |
| (phage)                      | <i>E. coli</i> C3000               | LP?   | 2.1 | 4.2 | 6.4 | 8.5  | 11  | 13 | yes        |       | Battigelli et al. 1993  |
| (phage)                      | <i>E. coli</i> ATCC 15597          | LP?   | 4   | 8   | 12  |      |     |    | no         |       | Oppenheimer et al. 1993 |
| (phage)                      | <i>E. coli</i> WG5                 | LP  | 2.2 | 5.3 | 7.3 | 10.5 |     |    | yes        |       | Sommer et al. 1998      |
| (phage)                      | <i>E. coli</i> ATCC 13706          | LP  | 2.0 | 3.5 | 5   | 7    |     |    | yes        |       | Giese & Darby 2000      |
| (phage)                      | <i>E. coli</i> WG5                 | LP  | 3   | 5   | 7.5 | 10   | 13  | 15 | yes        |       | Sommer et al. 2001      |
|                              | N/A                                | UV-LED 255 nm   | 1.6 | 3.3 | 5.1 |      |     |    | yes        |       | Aoyagi et al. 2011      |
|                              | N/A                                | UV-LED 280 nm   | 2.3 | 5.1 | 8.6 |      |     |    | yes        |       | Aoyagi et al. 2011      |
| ATCC 13706                   | N/A                                | LP  | 7.1 | 14  | 21  | 28   | 37  | 47 | yes        |       | Timchak & Gitis 2012    |
|                              | <i>E. coli</i> CN13                | LP  | N/A | N/A | N/A | 8.9  |     |    | yes        |       | Rodriguez et al. 2014   |
|                              | <i>E. coli</i> CN13                | MP  | N/A | N/A | N/A | 6.7  |     |    | yes        |       | Rodriguez et al. 2014   |

|  |  | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |     |     |    |     |     |              |           |       |                          |  |
|--|--|---|-----|-----|----|-----|-----|--------------|-----------|-------|--------------------------|--|
| Virus  | Host                                   | Lamp Type   | 1   | 2   | 3  | 4   | 5   | 6            | Protocol? | Notes | Reference                |  |
| <b>Picornaviridae aphthovirus</b> (foot and mouth disease virus) |  |   |     |     |    |     |     |              |           |       |                          |  |
| O189   | baby hamster kidney (BHK-21) cell line | LP  | 25  | 50  | 75 | 100 |     |              | no        | (5)   | Nuanualsuwan et al. 2008 |  |
| A132   | baby hamster kidney (BHK-21) cell line | LP  | 20  | 39  | 59 | 78  |     |              | no        | (5)   | Nuanualsuwan et al. 2008 |  |
| A Sakol  | baby hamster kidney (BHK-21) cell line | LP  | 22  | 44  | 67 | 89  |     |              | no        | (5)   | Nuanualsuwan et al. 2008 |  |
| AS 1   | baby hamster kidney (BHK-21) cell line | LP  | 31  | 63  | 94 | 125 |     |              | no        | (5)   | Nuanualsuwan et al. 2008 |  |
| <b>Poliovirus</b>  |  |   |     |     |    |     |     |              |           |       |                          |  |
| Type 1 LSc2ab  | MA104 cells                            | LP  | N/A | 5.6 | 11 | 17  | 22  |              | yes       |       | Chang et al. 1985        |  |
| Type 1 ATCC Mahoney  | N/A                                    | LP  | 6   | 14  | 23 | 30  |     |              | yes       |       | Harris et al. 1987       |  |
| Type 1 LSc2ab  | BGM cell line                          | LP  | 2.8 | 11  | 20 | 28  | 37  | 46           | yes       |       | Wilson et al. 1992       |  |
| Type 1   | BGM cell line                          | LP  | 8.0 | 16  | 23 | 31  |     |              | yes       |       | Gerba et al. 2002        |  |
| Type 1 LSc2ab  | BGM cell line                          | LP  | 7   | 17  | 28 | 37  |     |              | yes       |       | Thompson et al. 2003     |  |
| Vaccine strain method: plaque assay                              | N/A                                    | LP  | 6.4 | 14  | 22 | 33  |     |              | no        |       | Lazarova & Savoye 2004   |  |
| Vaccine strain method: TCID50                                    | N/A                                    | LP  | 6.4 | 14  | 21 | 31  |     |              | no        |       | Lazarova & Savoye 2004   |  |
| Type 1   | BGM cell line                          | LP  | 8.7 | 17  | 25 |     |     |              | yes       |       | Shin et al. 2005         |  |
| Type 1   | BGM cell line                          | LP  | 7   | 14  | 21 | 29  | 39  | 50 + tailing | yes       |       | Simonet & Gantzer 2006   |  |
| <b>PRD-1 (Tectiviridae)</b>                                      |  |   |     |     |    |     |     |              |           |       |                          |  |
| phage  | <i>Salmonella typhimurium</i> Lt2      | LP  | 10  | 17  | 24 | 30  |     |              | yes       |       | Meng & Gerba 1996        |  |
| ATCC BAA-769-B1  | <i>Salmonella typhimurium</i> Lt2      | LP  | 18  | 50  | 81 | 108 | 138 |              | yes       |       | Shin et al. 2005         |  |

|                                     |                                      | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |     |     |     |    |    |    |            |                 |                           |
|-------------------------------------|--------------------------------------|---|-----|-----|-----|----|----|----|------------|-----------------|---------------------------|
| Virus                               | Host                                 | Lamp Type   | 1   | 2   | 3   | 4  | 5  | 6  | Proto-col? | Notes           | Reference                 |
| <b>PRD-1 (Tectiviridae) (cont.)</b> |                                      |   |     |     |     |    |    |    |            |                 |                           |
|                                     | <i>Salmonella typhimurium</i> Lt2    | LP  | N/A | N/A | N/A | 36 |    |    | yes        |                 | Rodriguez et al. 2014     |
|                                     | <i>Salmonella typhimurium</i> Lt2    | MP  | N/A | N/A | N/A | 32 |    |    | yes        |                 | Rodriguez et al. 2014     |
| <b>Q<math>\beta</math></b>          |                                      |   |     |     |     |    |    |    |            |                 |                           |
|                                     | N/A                                  | UV-LED 255 nm   | 11  | 23  |     |    |    |    | yes        |                 | Aoyagi et al. 2011        |
|                                     | N/A                                  | UV-LED 280 nm   | 27  |     |     |    |    |    | yes        |                 | Aoyagi et al. 2011        |
|                                     | <i>E. coli</i> ATCC 15597 C3000      | LP  | 12  | 25  | 40  |    |    |    | yes        |                 | Jenny et al. 2014         |
|                                     | <i>E. coli</i> ATCC 15597 C3000      | UV-LED 260 nm   | 9   | 19  | 29  | 41 |    |    | yes        |                 | Jenny et al. 2014         |
| ATCC 23631-B1                       | <i>E. coli</i> ATCC 23631            | LP  | 8   | 18  | 28  | 40 |    |    | yes        |                 | Blatchley III et al. 2008 |
| ATCC 23631-B1                       | <i>E. coli</i> ATCC 23631            | LP  | N/A | 20  |     |    |    |    | yes        | Action spectrum | Beck et al. 2015          |
| ATCC 23631-B1                       | <i>E. coli</i> ATCC 23631            | laser 254 nm  | 11  | 22  | 34  | 46 |    |    | yes        | Action spectrum | Beck et al. 2015          |
| phage                               | <i>E. coli</i> Hfr K12 ATCC 23631    | LP  | 12  | 23  | 36  | 50 | 66 | 83 | yes        |                 | Simonet & Gantzer 2006    |
| phage                               | <i>E. coli</i> K12 A/ $\lambda$ (F+) | LP  | 10  | 23  | 35  |    |    |    | yes        |                 | Rattanakul et al. 2014    |
| ATCC 23631 B1                       | <i>E. coli</i> K12 A/ $\lambda$ (F+) | UV-LED 285 nm   | 27  | 54  | 81  |    |    |    | yes        |                 | Oguma et al. 2015         |
| phage                               | <i>E. coli</i> K12 A/ $\lambda$ (F+) | LP  | 11  | 26  | 40  | 55 |    |    | yes        |                 | Oguma et al. 2013         |
| <b>Reovirus</b>                     |                                      |   |     |     |     |    |    |    |            |                 |                           |
| 3                                   | Mouse L-60                           | LP?   | 11  | 22  |     |    |    |    | yes        |                 | Rauth 1965                |
| Type 1 Lang strain                  | N/A                                  | LP  | 16  | 36  |     |    |    |    | yes        |                 | Harris et al. 1987        |

|   |                                 | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |     |     |              |               |     |    |           |                 |                        |  |
|---|---------------------------------|---|-----|-----|--------------|---------------|-----|----|-----------|-----------------|------------------------|--|
| Virus   | Host                            | Lamp Type   | 1   | 2   | 3            | 4             | 5   | 6  | Protocol? | Notes           | Reference              |  |
| <b>Rotavirus</b>  |                                 |   |     |     |              |               |     |    |           |                 |                        |  |
| SA-11   | Monkey kidney Cell line MA 104  | LP  | 8   | 15  | 27           | 38            |     |    | yes       |                 | Sommer et al. 1989     |  |
|   | MA 104 cell line                | LP  | 20  | 80  | 140          | 200           |     |    | no        |                 | Caballero et al. 2004  |  |
| SA-11   | MA 104 cell line                | LP  | 7   | 15  | 25           |               |     |    | yes       |                 | Chang et al. 1985      |  |
| SA-11   | MA 104 cell line                | LP  | 9   | 19  | 26           | 36            | 48  |    | yes       |                 | Wilson et al. 1992     |  |
| SA-11   | MA 104 cell line                | LP  | 7   | 15  | 23           |               |     |    | yes       |                 | Battigelli et al. 1993 |  |
| 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       |                 | Li et al. 2009         |  |
| SA-11 ATCC VR-1565 method: RT-qPCR assay                    | MA 104 cells ATCC CRL-2378.1    | LP  | 29  | 58  | 88           | 117 + tailing |     |    | yes       |                 | Li et al. 2009         |  |
| Human (HRV-Wa)  | N/A                             | LP  | 16  | 24  | 32           | 40            |     |    | yes       |                 | Hu et al. 2012         |  |
| SA-11   | MA-104 cell line                | LP  | 10  | 21  | 32           | 43            | 53  |    | yes       |                 | Wilson et al. 1992     |  |
| <b>Siphoviridae</b>   | <i>E. coli</i> C                | LP  | 1.8 | 3.6 | 5.7          | 7.5           | 9.3 |    | yes       |                 | Shin et al. 2005       |  |
| <b>T1</b>   |                                 |   |     |     |              |               |     |    |           |                 |                        |  |
|   | <i>E. coli</i> CN13             | LP  | N/A | N/A | N/A          | 13            |     |    | yes       |                 | Rodriguez et al. 2014  |  |
|   | <i>E. coli</i> CN13             | MP  | N/A | N/A | N/A          | 19            |     |    | yes       |                 | Rodriguez et al. 2014  |  |
| <b>T1UV</b>   |                                 |   |     |     |              |               |     |    |           |                 |                        |  |
| HER 468   | <i>E. coli</i> CN13 ATCC 700609 | LP  | N/A | 8.3 |              |               |     |    | yes       | Action spectrum | Beck et al. 2015       |  |
| HER 468   | <i>E. coli</i> CN13 ATCC 700609 | Laser 254 nm  | 4.3 | 8.5 | 13           | 17            |     |    | yes       | Action spectrum | Beck et al. 2015       |  |
| <b>T4</b>   |                                 |   |     |     |              |               |     |    |           |                 |                        |  |
|   | <i>E. coli</i>                  | LP  | 1.1 | 2.0 | 3.0          | 4.0           | 6.7 |    | yes       |                 | Bohrerova et al. 2008  |  |
|   | <i>E. coli</i>                  | MP  | 1.1 | 1.7 | 2.6          | 4.0           | 7   |    | yes       |                 | Bohrerova et al. 2008  |  |
|   | <i>E. coli</i>                  | LP  | 3.6 | 8.0 | 13           |               |     |    | yes       |                 | Hu et al. 2012         |  |
| ATCC 11303  | N/A                             | LP  | 3.7 | 7.4 | 11           | 17            | 23  | 29 | yes       |                 | Timchak & Gitis 2012   |  |

|                                       |                                 | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |     |     |     |    |    |   |           |                 |                       |  |
|---------------------------------------|---------------------------------|---|-----|-----|-----|----|----|---|-----------|-----------------|-----------------------|--|
| Virus                                 | Host                            | Lamp Type   | 1   | 2   | 3   | 4  | 5  | 6 | Protocol? | Notes           | Reference             |  |
| <b>T7</b>                             |                                 |   |     |     |     |    |    |   |           |                 |                       |  |
|                                       | <i>E. coli</i>                  | LP  | 1.7 | 5.8 | 11  | 16 | 20 |   | yes       |                 | Bohrerova et al. 2008 |  |
|                                       | <i>E. coli</i>                  | MP  | 1.3 | 3.7 | 8   | 13 | 18 |   | yes       |                 | Bohrerova et al. 2008 |  |
| coliphage                             | <i>E. coli</i> ATCC 11303       | LP  | 2.7 | 6.0 | 11  |    |    |   | yes       |                 | Bowker et al. 2011    |  |
| coliphage                             | <i>E. coli</i> ATCC 11303       | LP  | 2.7 | 6.0 | 11  |    |    |   | yes       |                 | Bowker et al. 2011    |  |
| coliphage                             | <i>E. coli</i> ATCC 11303       | UV-LED 255 nm   | 2.9 | 6.9 | 14  |    |    |   | yes       |                 | Bowker et al. 2011    |  |
| coliphage                             | <i>E. coli</i> ATCC 11303       | UV-LED 275 nm   | 2.7 | 6.0 | 12  | 17 |    |   | yes       |                 | Bowker et al. 2011    |  |
| ATCC BAA-1025-B2                      | <i>E. coli</i> CN13 ATCC 700609 | LP  | N/A | 3.8 |     |    |    |   | yes       | Action spectrum | Beck et al. 2015      |  |
| ATCC BAA-1025-B2                      | <i>E. coli</i> CN13 ATCC 700609 | Laser 254 m   | 1.6 | 3.6 | 6.6 |    |    |   | yes       | Action spectrum | Beck et al. 2015      |  |
| <b>T7m</b>                            |                                 |   |     |     |     |    |    |   |           |                 |                       |  |
| ATCC 11303-B38                        | <i>E. coli</i> B ATCC 11303     | LP  | N/A | 3.4 |     |    |    |   | yes       | Action spectrum | Beck et al. 2015      |  |
| ATCC 11303-B38                        | <i>E. coli</i> B ATCC 11303     | Laser 254 m   | 1.7 | 3.8 | 6.3 | 11 |    |   | yes       | Action spectrum | Beck et al. 2015      |  |
| <b>V<sub>1</sub></b><br>(Podoviridae) | <i>E. coli</i> WG5              | LP  | 3.1 | 5.9 | 8.8 |    |    |   | yes       |                 | Shin et al. 2005      |  |

**Table 5.** Fluences for multiple log reductions for various algae and other microorganisms

| Microorganism   | Lamp Type | Fluence (UV dose) (mJ/cm <sup>2</sup> ) for a given log reduction without photoreactivation |               |      |   |   | Protocol? | Notes | Reference              |
|---|-----------|---|---------------|------|---|---|-----------|-------|------------------------|
|   |           | 1   | 2             | 3    | 4 | 5 |           |       |                        |
| <b><i>Ascaris suum</i></b>  |           |   |               |      |   |   |           |       |                        |
| (intact eggs) from worms  | LP        | 100   | 328 + tailing |      |   |   | yes       |       | Brownell & Nelson 2006 |
| (decorticated eggs) from worms  | LP        | 30  |               |      |   |   | yes       |       | Brownell & Nelson 2006 |
| <b><i>Cryptococcus carnescens</i></b> yeast PYCC 5988                               | LP        | 18  | 32            |      |   |   | yes       |       | Pereira et al. 2013    |
| <b><i>Candida sp.</i></b> New species similar to <i>C. pomicola</i> yeast PYCC 5991 | LP        | <10   | 25            |      |   |   | yes       |       | Pereira et al. 2013    |
| <b><i>Metschnikowia viticola/Candida kofuensis</i> yeast</b>                        |           |   |               |      |   |   |           |       |                        |
| PYCC 5993   | LP        | 10  | 20            |      |   |   | yes       |       | Pereira et al. 2013    |
| PYCC 5994   | LP        | 8   | 17            |      |   |   | yes       |       | Pereira et al. 2013    |
| <b><i>Metschnikowia viticola/Candida kofuensis</i></b> yeast PYCC 5992              | LP        | 10  | 23            |      |   |   | yes       |       | Pereira et al. 2013    |
| <b><i>Microcystis aeruginosa</i></b>  |           |   |               |      |   |   |           |       |                        |
| PCC7806   | LP        | 10  | 28            | >60  |   |   | no        |       | Sakai et al. 2011      |
| PCC7806   | MP        | 15  | 130           | >200 |   |   | no        |       | Sakai et al. 2011      |
| <b><i>Rhodospiridium babjevae</i></b> yeast PYCC 5996                               | LP        | 40  | 90            |      |   |   | yes       |       | Pereira et al. 2013    |
| <b><i>Rhodotorula minuta</i></b> (Saito) yeast PYCC 5990                            | LP        | 43  | 90            |      |   |   | yes       |       | Pereira et al. 2013    |
| <b><i>Rhodotorula mucilaginosa</i> yeast</b>  |           |   |               |      |   |   |           |       |                        |
| PYCC 5989   | LP        | 44  | 81            |      |   |   | yes       |       | Pereira et al. 2013    |
| PYCC 5995   | LP        | 57  | 113           |      |   |   | yes       |       | Pereira et al. 2013    |
| <b><i>Saccharomyces cerevisiae</i></b> XS800  | LP        | 42  | 70            | 100  |   |   | no        |       | Kim et al. 2004        |
| <b><i>Tetraselmis suecica</i></b> algae K0297                                       | LP        | 370   | 540           | 720  |   |   | no        |       | Olsen et al. 2015      |

## Table Notes

1. Spiked into wastewater.
2. These data are medians derived from a Bayesian analysis of many studies.
3. DNA weighted fluence.
4. Action spectrum weighted fluence.
5. 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.

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