UVC Sterilization Chamber

UVB-42X3 Efficacy Study on Dosage & Time

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Introduction

The Bioforge team has designed and developed a UVC sterilization chamber (UVB-42X3) that can reach upto 99.999% sterility in under an hour. After carefully studying a number of peer reviewed papers on the effects of Ultraviolet germicidal irradiation on the coronavirus, we started designing our own version of a UVC sterilization chamber. We started with determining the maximum possible UV-C exposure required to eliminate SARS CoV-2 from most surfaces. We have looked in-depth at how the time required to disinfect not just the COVID-19 virus but also other viruses and bacteria that stays in the air as aerosols.

What is Ultraviolet Germicidal Irradiation

Ultraviolet Germicidal Irradiation (UVGI) is a disinfection method that uses short-wavelength ultraviolet (Ultraviolet C or UV-C) light to inactivate microorganisms by destroying nucleic acids and disrupting their DNA, leaving them unable to perform vital cellular functions. UVGI is used in a variety of applications, such as food, air, and water purification.

Surface Disinfection using UV Lights

Direct UVGI exposure can sterilize any surface given enough time. UV is highly effective at controlling microbial growth and at achieving sterilization of most types of surfaces. Early applications included equipment sterilization in the medical industry. Modern applications include pharmaceutical product disinfection, area disinfection, cooling coil and drain pan disinfection, and overhead UV systems for surgical suites[1].

Effects of UV lights on the Coronavirus (SARS CoV-2)

An extensive test was conducted by Wladyslaw J. Kowalski (PurpleSun), Thomas J Walsh (PurpleSun) and Vidmantas Petraitis (Weill Cornell Medicine of Cornell University) and the report was released in March, 2020. This report addresses a topic of current interest - the ultraviolet susceptibility of SARS-CoV-2.

The results of a literature review are presented and summarized to provide a basis for estimating the ultraviolet susceptibility of SARS-CoV-2, and relevant supplemental information is provided on COVID-19, based on the latest published reports[2].

The average dosage found to inactivate 90% of the SARS-CoV-2 particulates (D_{90}) was found to be 27 J/m^2.

Microbe	D_{90} Dose (J/m^2)	UV (k m^2/J)	Base Pairs (kb)	Source
Coronavirus	6.6	0.35120	30741	Walker 2007[a]
Berne Virus (Coronaviridae)	7.2	0.32100	28480	Weiss 1986
SARS-CoV-2 (Italy-INMI1)	12.3	0.18670	29811	Bianco 2020
Murine Coronavirus (MHV)	15.0	0.15351	31335	Hirano 1978
SARS Coronavirus (Frankfurt 1)	16.4	0.14040	29903	Eickmann 2020
Canine Coronavirus (CCV)	28.5	0.08079	29278	Saknimit 1988[b]
Murine Coronavirus (MHV)	28.5	0.08079	31335	Saknimit 1988[b]
SARS Coronavirus (CoV-P9)	40.0	0.05750	29829	Duan 2003[c]
SARS-CoV-2 (SARS-CoV-2/Hu/DP/Kng/19-027	41.7	0.05524	29811	Inagaki 2020
Murine Coronavirus (MHV)	103.0	00.02240	31335	Liu 2003
SARS Coronavirus (Hanoi)	133.9	0.01720	29751	Kariwa 2004[d]
SARS Coronavirus (Urbani)	2410	0.00096	29751	Darnell 2004
Average	**237**	**0.00972**	Including all studies	
Average excluding outliers	**47**	**0.04943**	Excluding Walker, Weiss & Darnell	
Average for SARS-CoV-2	**27**	**0.08528**	Two studies, 90% inactivation	

[a](Jingwen 2020) *[b](estimated)* *[c](mean estimate)* *[d](at 3 logs)*

Table 1: Summary of UV dose required to inactivate coronaviruses[1]

There have been numerous studies conducted to estimate the inactivation dosages required for SARS-CoV-2, within a given accuracy. Paolo Arguelles (Cornell University). The research was published in April, 2020. The time of exposure, distance from the lamp, power of the lamps used for sterilization were all taken into account during the calculation[3].

Study	D_{90}	$D_{99.9}$	$D_{99.99}$	$D_{99.999}$
Walker, 2007	7	-	-	-
Duan, 2003	9	-	-	-
Kariwa, 2006	-	134	-	-
Eickmann, 2020	-	5000	10000 - 15000	-
Darnell, 2004	2410	6020	12050	36144

** values are approximate and expressed in J/m²*

Table 2: Literature Review of SARS-CoV-1 Inactivation Dosages[2]

The highest dosage found; 36144 J/m^2 was considered and all the losses in power were taken into while calculating the time of exposure from our 14W UVC lamps. The following equations were used to accurately calculate the amount of exposure required for 99.999% sterilization[2].

$$D = It$$

$$I = \frac{P_{UVC}}{A_{\text{exposed}}} = \frac{\eta P}{4\pi r^2}$$

$$t \approx 1.5 \times 10^6 (\frac{\pi r^2}{P})$$

Inactivation dosage targeted towards SARS-CoV-2	Value (J/m^2)
D1, 99.999 %	36144
D2, 99.9 %	6020

Table 3: Dosage required 99.999% and 99.9% disinfection[2]

Power of Lamp (W)	Number of Lamps (n)	Distance (inch)	Disinfection Time, D1 (min)	Disinfection Time, D2 (min)
14	2	5.7	**58.82**	**14.5**

Table 4: Summary of UVB-42X3 sterilization time

Micro-organism	90% disinfection ($rnWsec/cm^2$)	99.9% disinfection ($rnWsec/cm^2$)	Micro-organism	90% disinfection ($rnWsec/cm^2$)	99.9% disinfection ($rnWsec/cm^2$)
Bacterien, Viren			Proteus vulgaris	2.7	7.8
Bacterium coli (in air)	0.7	2.1	Pseudomonas aeruginosa	5.5	16.5
Bacterium coli (in water)	5.4	16.2	Pseudomonas fluorescens	3.5	10.5
Bacilus anthracis	4.5	13.7	S. tyyphimurium	8.0	24.0
S. enteritidis	4.0	12.0	Sarcina lutea	19.8	59.0
B. megatherium (veg.)	1.1	3.4	Serratia marcescens	2.5	7.2
B. megatherium sp.	2.8	8.0	Dysentery bacilli	2.2	6.6
B. paratyphosus	3.2	9.6	Shigella paradysenteria e	1.7	5.2
13, prodiglosus	0.7	2.1	Spirillum rubrurn	4.4	13.0
B. pyocyaneus	4.4	13.2	Staphylococcus albus	1.8-3.3	5.4-10.0

B. subtilis spores	12.0	36.0	**Staphylococcus aureus**	2.2-4.9	6.6-14.8
Cornyebacterium diphteriae	3.4	10.0	**Streptococcus hemolyticus**	2.2	6.6
Eberthella typhosa	2.1	6.3	**Streptococcus lactis**	6.1	18.0
Escherichia coli	3.0	9.0	**Streptococcus viridans**	2.0	6.0
Legionella pneumophila	0.92	2.76	**Baccillus tuberculi**	10.0	30.0
Micrococcus candidus	6.3	19.0	**Trichonomas**	100.0	300.0
Micrococcus piltonensis	8.1	24.0	**Poliovirus**	3.2	9.6
Micrococcus sphaeroides	10.0	30.0	**Infectus Hepatitis**	5.8	17.4
Neisseria catarrhalls	4.4	13.0	**Influenza**	3.4	10.2
Phytomonas tumefaciens	4.4	13.0	**Tobaco mosaic**	240	720

Table 5: UV-254nm doses for 90% and 99.9% inactivation of different microorganisms

Limitations of UVGI

As a number of studies have noted, there are many factors that can impede UVGI ability in practice[5],[6]. For N95 respirator disinfection applications, there are significant concerns as to whether UVGI systems can deliver the sufficient dosage to inactivate viral particles trapped within the fibers of the mask surface[7]. Shadowing effects must also be taken into consideration when designing UVGI systems[8].

It is important to note that while[4] demonstrated a 5-log reduction in SARS-CoV-1 concentration, this should not be taken to mean that sterilized surfaces no longer pose an infectivity threat. For surfaces containing extremely high viral loads, for instance, 99.999% inactivation does not necessarily translate to complete sterilization. In one recent study, researchers reported SARS-CoV-2 viral loads (expressed in copies/mL) from COVID-19 patient samples ranging from 641 to 1.34×10^{11} with a reported median of 7.52×10^{5}[9]. Supposing a surface is infected with the median value, a theoretical 5-log reduction in virus concentration would decrease the viral load to 100 copies/mL. However, taking the upper bound of the dataset would still leave a viable residual viral load of 106 copies/mL.

Conclusion

After considering all the factors we went with the highest dosage required for the inactivation of not just the SARS CoV-2 virus but most of the common bacterias that might exist on the surface to be sterilized. We have designed our sterilization in a way that allows it to reach upto 99.999% sterility in under one hour. There can be other variables involved in the process that can regulate the time, such as any sort of shadow casted on the material to be disinfected, degradation of the lamp, percentage of humidity present in the air, etc. The energy required might also be different for different materials.

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