PURE UVC Whole Room Air and Surface Disinfection Testing Results

Introduction:

UV-C irradiation, when correctly applied, will render the SARS-CoV-2 virus inactive and can be vital in containing the spread of COVID-19[1]. Properly calculated dosages of direct UV-C illumination will deactivate the DNA of bacteria, viruses and other pathogens within the air and on surfaces to destroy their ability to multiply. The benefits of UV-C lighting over other methods of disinfection such as chemicals are numerous and include no dangerous residue, no harmful odors, and negligible renewal costs. Per the CDC, "The daily number of calls to poison centers increased sharply at the beginning of March 2020 [beginning of pandemic in the United States] for exposures to both cleaners and disinfectants.[2]" Pure UVC's solution allows for automated disinfection without exposing facility occupants to any harmful vapors, fumes, or by-products. The PURE UVC system has been professionally engineered with 5 levels of safety settings that ensure operation during periods of non-occupancy[3]; ensuring that UVC is a safe and efficient solution. As a matter of fact, even the CDC recommends using UV-C light for disinfection of Personal Protective Equipment (PPEs)[4]. It is the purpose of this experiment as well as our Pure UVC's mantra to utilize properly applied UV-C disinfection in order to lessen the usage of hazardous chemical cleaning products.

Calculations and Results:

In order to obtain dosage data for the PURE UVC fixture, PRFUVC4280IS, 2x2 Recessed UVC Troffer w/ Intelli-Safe Controls, 4 lamps, 2 ballasts, occupancy sensor, alarm annunciation and frictionless fan, a basic version was tested that only featured (2) 20W UVC lamps, 1 ballast and no fan. Lamps were placed at opposite ends of the 4-lamp fixture to simulate coverage, which has been determined to be approximately 30ft x 30ft at a 10ft height. This test was conducted in a room without air circulation. Measurements were taken at 2ft intervals along the X and Y axis directly from the light source in accordance with Figure 1 below. Measurements were recorded with a UV-C meter (PHPL220UV1-254) specifically calibrated for 254nm with a 0.1 µW /cm² resolution. Test location was isolated for any other types of radiation and lights were turned off during measurement taking.

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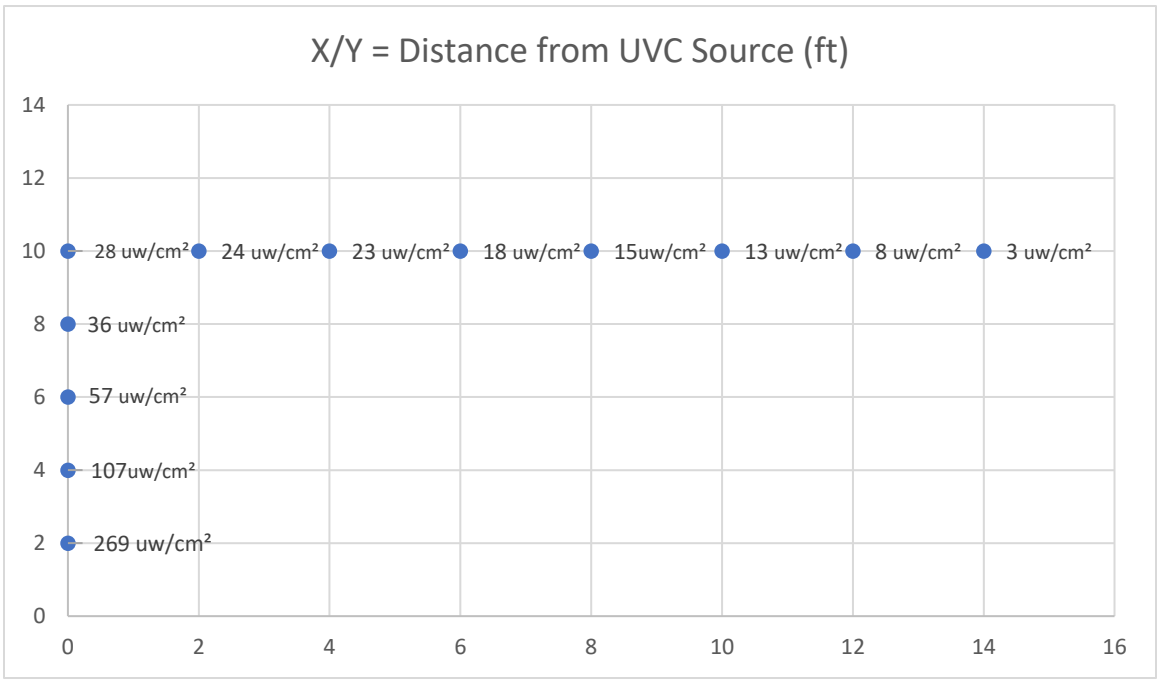

{Figure 1 – Dosage readings from UV-C source (0,0)}

The following calculation determines the dosage times required for a 2-log reduction of the selected pathogen per the inactivation factor specified in figure-2 below and in accordance with the specified dosage readings from figure-1 (please see the first comment in "Notes and Observations" concerning unit measurements).

- Coverage = (1) 2X2 PRFUVC4280IS fixture to not exceed 900ft² coverage at 10ft ceiling height:
- 28mj/cm² @ 10ft
- 120" factor: 28mj/cm² *1.00 = 28mj/cm² (Figure 3)
- 1-minute dosage = 28mj/cm² * 60 seconds = 1,680mj/cm²
- 1-hour dosage = 1,680mj/cm² * 60 minutes = 100,800mj/cm²
- Anti-Viral: 99% reduction of Influenza = 6,600mj/cm² / 1,680mj/cm² => 4 minutes
- Anti-Bacterial: 99% reduction of Sarcina lutea = 26,400mj/cm² / 1,680mj/cm² => 16 minutes
- Anti-Mold 99% reduction of Aspergillius flavus = 99,000mj/cm² / 100,800mj/cm² => 1hr

Energy Dosage of Ultraviolet radiation (UV dose) in µWs/cm^2 needed for inactivation factor

Bacteria	90% (1 log reduction)	99% (2 log reduction)
Bacillus anthracis - Anthrax	4,520	8,700
Bacillus anthracis spores - Anthrax spores	24,320	46,200
Bacillus magaterium sp. (spores)	2,730	5,200
Bacillus magaterium sp. (veg.)	1,300	2,500
Bacillus paratyphusus	3,200	6,100
Bacillus subtilis spores	11,600	22,000

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Bacillus subtilis	5,800	11,000
Clostridium tetani	13,000	22,000
Corynebacterium diphtheriae	3,370	6,510
Ebertelia typhosa	2,140	4,100
Escherichia coli	3,000	6,600
Leptospiracanicola - infectious Jaundice	3,150	6,000
Micrococcus candidus	6,050	12,300
Micrococcus sphaeroides	1,000	15,400
Mycobacterium tuberculosis	6,200	10,000
Neisseria catarrhalis	4,400	8,500
Phytomonas tumefaciens	4,400	8,000
Proteus vulgaris	3,000	6,600
Pseudomonas aeruginosa	5,500	10,500
Pseudomonas fluorescens	3,500	6,600
Salmonella enteritidis	4,000	7,600
Salmonela paratyphi - Enteric fever	3,200	6,100
Salmonella typhosa - Typhoid fever	2,150	4,100
Salmonella typhimurium	8,000	15,200
Sarcina lutea	19,700	26,400
Serratia marcescens	2,420	6,160
Shigella dyseteriae - Dysentery	2,200	4,200
Shigella flexneri - Dysentery	1,700	3,400
Shigella paradysenteriae	1,680	3,400
Virus	90%	99%
Bacteriopfage - E. Coli	2,600	6,600
Infectious Hepatitis	5,800	8,000
Influenza	3,400	6,600
Poliovirus - Poliomyelitis	3,150	6,600
Tobacco mosaic	240,000	440,000
Molds	90%	99%
Aspergillius flavus	60,000	99,000
Aspergillius glaucus	44,000	88,000
Aspergillius niger	132,000	330,000
Mucor racemosus A	17,000	35,200
Mucor racemosus B	17,000	35,200
Oospora lactis	5,000	11,000
Penicillium expansum	13,000	22,000

{Figure 2 –Germicidal UV UV-C Irradiation Dosages. Source: https://www.americanairandwater.com/uv-facts/uv-dosage.htm}

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Notes and Observations:

- Microwatts expressed as µWs and microjoules per second mJ/cm² represent the same dosage and are used interchangeably.
- The results of this experiment indicate that lack of air mixing can decrease effectiveness by almost 30% when compared to testing performed with a fan in place.
- Mold organisms requiring higher energy dosages such as Aspergillius niger (330,000mj/cm² kill factor) will require longer manually scheduled treatment sessions.
- Rooms larger than the 900ft² measured area and/or employing non-rectangular geometry or with low ceilings will require more fixtures for proper coverage regardless of dosage values.
- At least two lights per intended dosage area are recommended where obstructions (i.e. tables, chair, floor furniture, etc..) occur. This will result in significantly improved coverage as a result of two light sources from different angles filling in each other's shadows. Improved coverage will lead to improved treatments.

Intensity Factor	
DISTANCE FROM LAMP (INCHES)	INTENSITY FACTOR
2	32.3
3	22.8
4	18.6
6	12.9
8	9.85
10	7.94
12	6.48
14	5.35
18	3.6
24	2.33
36	1.22
* 39.37 (one meter)	1.00
48	.681
60	.452
80	.256
100	.169
120	.115

{Figure 3 – Intensity Factor Chart. Source: ASHRAE. (2015). ASHRAE handbook}

Analysis:

The American Society for Microbiology explains how UVC irradiation inactivates viral, bacterial and fungal aerosols[5]. This article states that irradiation dosages from 1.5 through 45mJ/cm² lead to 4-5-log reductions (99.99%-99.999%) for the corresponding aerosol. These recommended dosage values are backed by the IUVA, International Ultraviolet Association, which states "Most regulatory bodies now specify a fluence or UV dose of 40 mJ/cm² (note that 1 mWs = 1 mJ) to assure at least 4 logs inactivation of any pathogenic microorganisms. Since the fluence or UV dose applied is independent of the medium, this requirement would also apply to air.[6]" Dosage values for comparable viruses in the same SARS virus family are 10-20 mJ/cm² using direct UVC light at a wavelength of 254nm; this dosage will achieve 99.9% disinfection (i.e., inactivation) under controlled lab conditions. In real-life conditions, the virus is often hidden or shaded from direct UVC light, reducing UVC's effectiveness. To compensate, researchers are applying dosages of 1,000 - 3,000 mJ/cm² to ensure 99.9% deactivation per the current CDC disinfection goal (see CDC's recently published guidelines, online). This value is in accordance with the calculations for a 99% 2-log reduction; furthermore, since testing was performed without adequate air mixing and at 50% lamp capacity, the results can be doubled and increased by 30% (on account of air mixing) to obtain optimal 4 lamp PRFUVC4280IS dosage results. For the sake of these findings 99% equivalencies on the UV Dosage table below can been increased from a 2-log reduction to a 3-log reduction to account for a more than twofold increase in actual dosage for the PRFUVC4280IS fixture.

Conclusion:

This experiment's results are in accordance with published criteria for 3-log and higher pathogen inactivation as specified in the citations below. The PRFUVC4280IS fixture at 2-lamps corresponds to the smallest emitted

wattage from the PURE UVC fixture product line. UV-C dosage values well in excess of 40mJ/cm² are anticipated because the PURE UVC fixtures feature 2-4 lamps per fixture along with treatment times that last between 5 minute anti-viral and 1hour comprehensive dosages. Therefore, we can conclude that the PURE UVC product line is a scientifically-backed disinfection solution that ensures deactivation of the SARS-CoV-2 virus and other pathogens by exceeding dosage value requirements for 99.9% disinfection as per above.

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