**Supplementary material: Colorimetric indicators and irradiance measurements to assess the dose of UV-C delivered by UV-C room decontamination devices**

ICHE 43598: A do-it-yourself test protocol using commercial *Bacillus atrophaeus* spores to evaluate the effectiveness of ultraviolet-C light room decontamination devices

**Background**

In addition to assessments of reduction in microbes, the dose of ultraviolet-C (UV-C) delivered by room decontamination devices can be assessed using radiometers and colorimetric indicators. Both methods have limitations but can provide valuable adjunctive information on UV-C dosing. Commercial colorimetric indicators provide only rough estimates of UV-C delivery but have the advantage of being inexpensive and easy-to-use.1 Results from colorimetric indicators have been shown to correlate reasonably well with irradiance measured using a radiometer.1-4 Colorimetric indicators have been used to assess UV-C delivery to different sites in patient rooms.1,4-6 Radiometers can be used to measure instantaneous irradiance and accumulated UV-C dose (fluence). Although radiometers can be used to compare UV-C devices, the equipment can be expensive and requires expertise and appropriate calibration.6

 As a supplement to the do-it-yourself test protocol using commercial *Bacillus atrophaeus* spores, we used a colorimetric indicator and a radiometer to assess the UV-C dose delivered by the 5 low-pressure mercury UV-C room decontamination devices used in laboratory testing. Findings for both these methods correlated well with microbial reductions of methicillin-resistant *Staphylococcus aureus* (MRSA) and *B. atrophaeus* and *Clostridioides difficile* spores.

**Colorimetric indicator testing**

UVC 100 Dosimeter Cards (Intellego Technologies AB, Gothenburg, Sweden) have a central circular indicator that is yellow in the absence of UV-C exposure. For reference, an outer circle shows orange and pink colors that indicate UV-C doses of approximately 50 and 100 mJ/cm², respectively. Per the manufacturer, a change of the central circular indicator to the orange color indicates a UV-C dose adequate to kill MRSA and other vegetative bacteria, whereas a change to the pink color indicates a dose adequate to kill *C. difficile* spores. A previous study provided a detailed evaluation of the UVC 100 Dosimeter Cards including correlation of color changes with UV-C dosing and reductions in microbes.1

The colorimetric dosimeter cards were used to provide a visual estimation of accumulated dose delivered by the 5 UV-C room decontamination devices used in the laboratory assessment. The dosimeter cards were exposed to UV-C while positioned parallel to lamps .914 meters from the device at the midpoint of the lamps. The dosimeter cards were exposed to the room disinfection device for ten minutes unless otherwise noted (ie, for the VORTEZ-UV device 30 minute and 60-minute cycles were included).

As shown in Figure 1, a 10-minute cycle with 4 of the devices provided a dose adequate to kill *C. difficile* spores based on change to pink color, whereas the VORTEX-UV device only provided a dose adequate to kill MRSA and other vegetative bacteria based on change to orange color. For the VORTEX-UV device, a 60-minute treatment time resulted in a dose adequate to kill *C. difficile* spores based on change to pink color. These findings are similar to our findings for reductions in *C. difficile* and *B. atrophaeus*. The VORTEX-UV device is a small device intended for decontamination of small rooms up to 20x20 feet in 15 minutes; for larger rooms, the manufacturer recommends concurrent use of multiple devices.

**Radiometer testing**

An ILT2500 radiometer (International Light Technologies) was used to record instantaneous irradiance and accumulated dose (fluence) for each of the 5 UV-C room decontamination devices used for laboratory testing. The sensor was exposed to UV-C while positioned parallel to lamps .914 meters from the device at the midpoint of the lamps. Readings were obtained over ten minutes unless otherwise noted (ie, for the VORTEX-UV device 30 minute and 60-minute cycles were included).

As shown in Table 1, 4 of the devices delivered greater than 87,900 µJ/cm2 over ten minutes, whereas the VORTEX-UV device delivered only 9,450 µJ/cm2 over ten minutes. With a 60-minute exposure time, the VORTEX-UV device delivered 56,700 µJ/cm2. In a previous study, a UV-C dose of 10,000 µJ/cm2 resulted in >3 log10 colony-forming unit (CFU) reduction in MRSA; for *C. difficile* spores, UV-C doses resulting in greater than 2 or 3 log10 CFU reductions were 25,000 and 46,000 µJ/cm2, respectively. Thus, the 60-minute cycle with the VORTEX-UV device provided a UV-C dose adequate to reduce *C. difficile* spores by >3 log10 CFU. These results are consistent with the reductions in *C. difficile* and *B. atrophaeus* spores achieved with the VORTEX-UV device.

**References**

1). Cadnum JL, Pearlmutter BS, Redmond SN, Jencson AL, Benner KJ, Donskey CJ. Ultraviolet-C (UV-C) monitoring made simple: Colorimetric indicators to assess delivery of UV-C light by room decontamination devices. *Infect Control Hosp Epidemiol* 2022;43:306-311.

2). Tande B, Pringle T, Rutala W, Gergen M, Weber D. Understanding the effect of ultraviolet light intensity on disinfection performance through the use of ultraviolet measurements and simulation. *Infect Control Hosp Epidemiol* 2018;39:1122-1124.

3). Boyce JM, Farrel PA, Towle D, Fekieta R, Aniskiewicz M. Impact of room location on UV-C irradiance and UV-C dosage and antimicrobial effect delivered by a mobile UV-C light device. *Infect Control Hosp Epidemiol* 2016;37:667-72.

4). Masse V, Hartley MJ, Edmond MB, Diekema DJ. Comparing and optimizing ultraviolet germicidal irradiation systems use for patient room terminal disinfection: an exploratory study using radiometry and commercial test cards. *Antimicrob Resist Infect Control* 2018;7:29.

5). Lindblad M, Tano E, Lindahl C, Huss F. Ultraviolet-C decontamination of a hospital room: Amount of light needed. *Burns* 2020;46:842-49.

6). Kreitenberg A, Martinello RA. Perspectives and recommendations regarding standards for ultraviolet-C whole-room disinfection in healthcare. *J Res Natl Inst Stan* 2021;126:126015.

**Figure 1. Pictures of UVC 100 Dosimeter Cards showing color changes after exposure to each UV-C device and the exposure time**



**Table 1. Measured irradiance (instantaneous) and accumulated UV-C dose (fluence) at .914 meters from the device**

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| --- | --- | --- |
| **Device/exposure time** | **Irradiance** | **Dose delivered** |
| **µW/cm2** | **µJ/cm2** |
| UVDI-360 Room Sanitizer/10 min  | 125 | 75,000 |
| Guardian/10 min | 219.5 | 131,700 |
| Tru-D/10 min | 208.1 | 124,860 |
| Rapid Disinfector/10 min | 146.5 | 87,900 |
| VORTEX-UV Portable UVC Room Sanitizer/10 min | 15.75 | 9,450 |
| VORTEX-UV Portable UVC Room Sanitizer/30 min | 15.75 | 28,350 |
| VORTEX-UV Portable UVC Room Sanitizer 60 min | 15.75 | 56,700 |