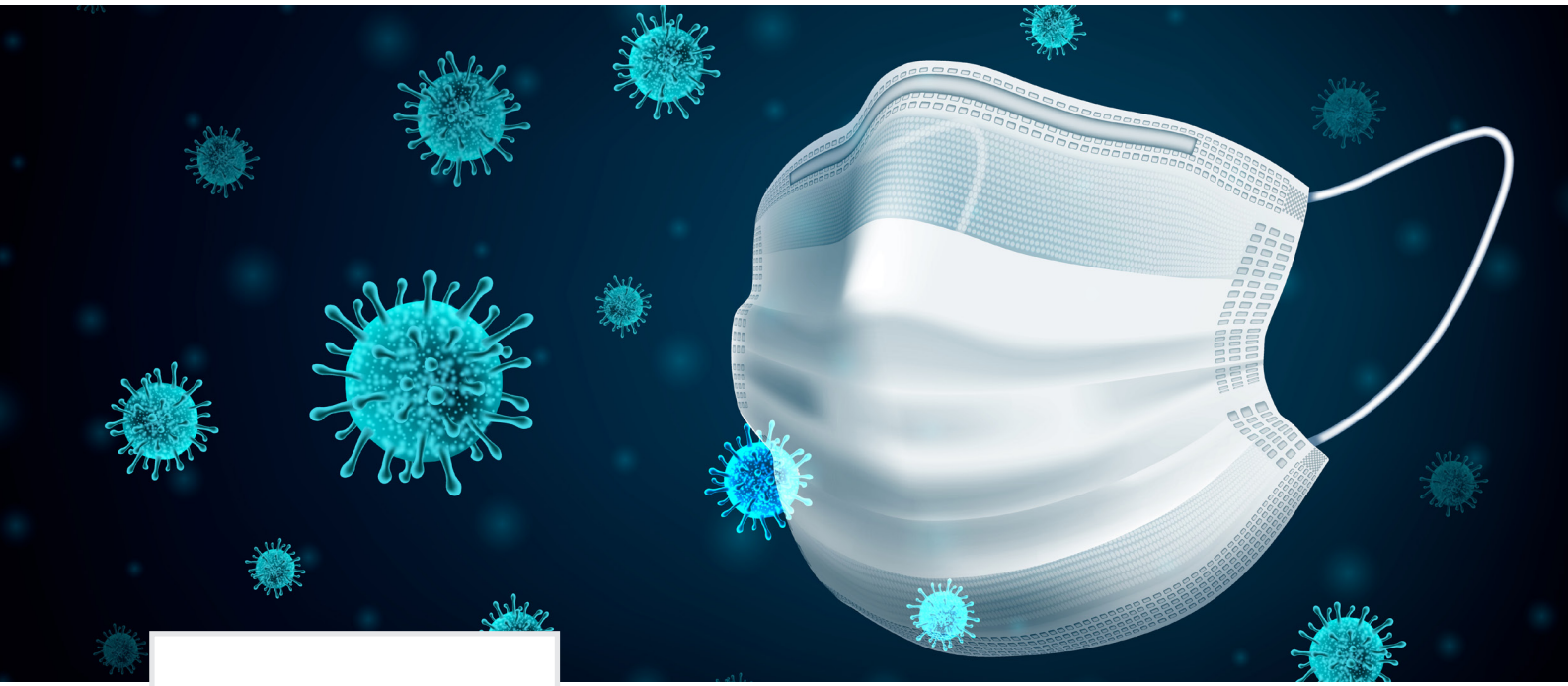

Ultraviolet-based Disinfection of N95 Respirator Masks

Abstract

Amid the ongoing SARS-CoV-2 outbreak, despite efforts by the private sector and governments globally, access to a steady supply of N95 respirator masks is lacking. An important mitigation approach to the limited supply of N95 masks is the irradiation and reuse of existing N95 masks, which the CDC contends is a promising strategy, especially during a pandemic[1]. Recently[2,3], a hospital-approved ultraviolet germicidal irradiation (UVGI) workflow for masks has become available. Ideally, healthcare workers (HCWs) should not routinely resort to reusing masks. However, if needed, the integration of the UVC-based CL-3000 crosslinker into a hospital-approved UVGI workflow will generate 1J/cm² of UVC with reproducible results.

Background

Shortwave ultraviolet light (UVC) has germicidal properties by acting directly on the DNA/RNA of microorganisms. DNA/RNA absorb ultraviolet light maximally at approximately 260 nm, which, as a consequence, damages the DNA/RNA structure. Although microorganisms have mechanisms with which to counteract this damage, they cannot overcome extensive high-intensity UV doses, which ultimately inactivate or kill the microorganism. Ultraviolet germicidal irradiation (UVGI) of viruses has been demonstrated extensively in the scientific literature for a range of viruses[4–37‡], and most recently for virus contaminated N95 filtering facepiece respirators (FFRs)[2,3,7,27,34‡‡].

Challenge

Access to a steady supply of N95 respirator masks is inadequate due to the COVID-19 pandemic

Solution

Irradiation and reuse of existing N95 masks using the UVP Crosslinker

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To prepare for inevitable shortages of N95 FFRs during the ongoing SARS-CoV-2 pandemic, the University of Nebraska Medical Center (UNMC) and Stanford University have developed UVGI workflows to be implemented by HCWs[2,3]. These workflows take advantage of UV equipment sometimes already found in the healthcare environment including, but not limited to, UV disinfection boxes[3] and whole-room UV emitters[2,15]. Some major concerns with these instruments are the lack of uniformity in germicidal light, the risk of inconsistent dosing between disinfection cycles, as well as the risk of UV exposure to HCWs in general[38,39]. At Analytik Jena we believe we have a better solution.

Since 1993 we have been supplying the UVP Crosslinker (CL-1000/CX-2000) primarily for molecular biology applications, which are reliant on high-intensity, reproducible UVC doses. By having reflective housing and the UV source in close proximity to the sample (Figure 1A), we are able to achieve highly uniform illumination (Figure 1B and 1C). Our most recent model, the CL-3000 (Figure 1A), is designed with a built-in radiometer calibrated to a NIST traceable standard—this ensures consistent doses irrespective of space and time. In addition, the CL-3000 can produce a cumulative dose of up to 10J/cm^2. As with all our instruments, safety of the end user is critical, and all our Crosslinkers have a safety-interlock to prevent accidental UV exposure. Most importantly, there is an extensive body of scientific work where our Crosslinker is used for viral inactivation of viruses from several families[11,18,19,24–26,31–33,35,36], including coronaviruses[21,23,30], which is lacking for other instruments on the market.

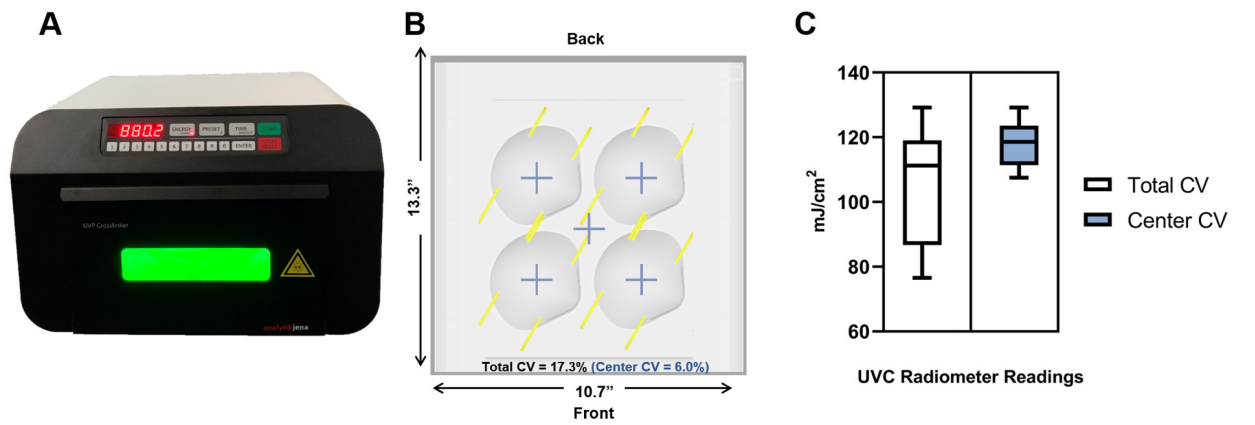

Figure 1. Uniformity of the Analytik Jena UVP Crosslinker equipped with 254 nm UVC bulbs. A) Profile image of the UVP CL-3000 Crosslinker during disinfection cycle. B) Diagram depicting position of integrated radiometer readings in mJ/cm² with dimensions and calculated coefficient of variation (CV) for the entire illumination surface (Total CV), and the center of the illumination surface (Center CV), the latter of which is where masks should be placed. C) Box-whisker plot summary of radiometer readings. Total CV: Mean =104.9, SD= 18.16; Center CV: Mean = 117.9, SD=7.1. We recommend users place masks in the center of the illumination to maximize evenness of UV exposure. Samples place in the center will receive, at a minimum, the input energy dose. If users want to place samples at the front-most and back-most positions, we recommend purchasing a UVP 254 nm radiometer (P/N 97-0015-02) and sensor (P/N 97-0016-01) to calibrate dose.

At Analytik Jena, we agree with the CDC, which contends that UVGI is a viable crisis strategy for capacity management of personal protective equipment[1]. In summary, our Crosslinker can be easily integrated into UVGI mask disinfection workflows for the following reasons:

- Fixed distance between sample and UVC source to ensure uniform dosing
- Embedded radiometer calibrated to NIST traceable standards to ensure reproducible dosing
- Higher UVC output for shorter disinfection cycles
- Safety Interlock to prevent accidental exposure
- Small footprint to accommodate limited spaces and/or decentralization
- Closed system to accommodate scaling up strategies
- Proven history of performance from the scientific literature

Operating the CL-3000 as part of an approved UVGI Workflow

According to an FDA commissioned report, a dose of 1J/cm^2 is sufficient to result in no detectable virus on N95 mask material after UVGI treatment, corresponding to a 3.9-4.5 $\log_{10}$ reduction for MERS-CoV and 4.0-4.8 $\log_{10}$ reduction for SARS-CoV, between experimental and control groups[34]. Below, we simply describe how to use our device to achieve the same irradiation level of 1J/cm^2. HCWs should inspect masks for wear and tear after each disinfection cycle[2,3,13,34].

To operate the CL-3000 simply follow the instructions below:

1. Set the dosage on the instrument by selecting ENERGY, then pressing 1-0-0-0-0 for 1000.0 mJ/cm^2 (or 1J/cm^2), and then press ENTER.
2. Place mask into the center-most portion of the chamber and close door.
3. Press START.
4. Open door and flip mask over and repeat step 3.
5. Remove the sample and continue following the UVGI protocol approved by your hospital/institution.

Note: As an added precaution, users may consider repeating steps 1-3 with an empty crosslinker in between disinfection cycles if residual contamination is a concern.

Disclaimer: We do not advocate specific treatments or approaches. We are simply sharing the most recent evidence from the medical community to help HCWs during the SARS-CoV-2 pandemic. Your UVGI workflow should be set and approved by your hospital/institution. Users can refer to the UNMC[2] and/or Stanford University[3] workflows for process recommendations.

Technical Data

Technical Specifications	CL-3000
Wavelength	**254nm**
Bulbs	**6 x 8 Watt**
Energy	**0000.1 - 9999.9 mJ/cm² (0 - 10 J/cm²)**
Time	**000:01 - 999:59 mmm:ss (>300J/cm²)**
Temperature	**15°C - 35°C**
Humidity	**70% Non-Condensing**
Altitude	**up to 3,000M (9,842 ft)**
Sound Level	**≤ 50 dba**
Housing Surface Temp	**≤ 30°C**
Startup Time	**< 1 sec**
External Dim (L x W x H)	**41cm x 40cm x 26.5cm**
Internal Dim (L x W x H)	**35cm x 27cm x 16cm**
Weight	**6.8Kg: 15 lb**
Operating Power	**100 - 115VAC & 230VAC 50/60Hz**
Certifications	**CE, RoHS (CSA In Process)**

Part Numbers and Description

Part Number	Description
849-95-0615-01	**UVP Crosslinker (CL-3000), 254 nm, 100 – 115V**
849-95-0615-02	**UVP Crosslinker (CL-3000), 254 nm, 230V**

Mid-Range Wavelength: 302 nm (CL-3000M) and Long-Range Wavelength: 365 nm (CL-3000L) UVP Crosslinkers are available to order, but are not applicable to this application note.

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‡These citations do not represent the entire body of literature for UVGI of viruses and only serve to represent the diversity of viruses that have been inactivated with UVGI.

‡‡ As of 4/7/2020 Ref. 2 & 3 have only been published online and are not peer-reviewed.

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