REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From – To)*
03-05-2020	Consultative Letter	May 4, 2020-May 5, 2020

4. TITLE AND SUBTITLE

Use of Ultraviolet Germicidal Irradiation (UVGI) for COVID-19 Decontamination Purposes

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Janiece Hope

Lawrence 'Kent' Harrington

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER
Legacy RHM

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Air Force Material Command; Air Force Research Lab
711th Human Performance Wing
Warfighter Medical Optimization Division
Wright-Patterson AFB, OH 45433

10. SPONSORING/MONITOR'S ACRONYM(S)
711 HPW/RHB

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
AFRL-RH-WP-CL-2020-0004

12. DISTRIBUTION / AVAILABILITY STATEMENT

DISTRIBUTION A. Approved for public release.

13. SUPPLEMENTARY NOTES
MSC/PA-2020-0220; 88ABW-2020-2929, cleared 29 Sept 2020

14. ABSTRACT

This document was crafted in response to multiple inquiries regarding the use of Ultraviolet Germicidal Irradiation (UVGI) for decontamination and includes general information on the use of UVGI. More specifically, this document includes detailed responses for two specific areas of concern that have been of interest in the DoD, decontamination and reuse of filtering facepiece respirators and the use of UVGI to disinfect an occupied space. 711 HPW/RHM has developed this framework for operational/maintenance risk analysis based on the best known available information. Ultimately, the acceptance of risk rests solely on the commander who is best positioned to understand the complexities of the operational, maintenance, and mission requirements of their unit. It is impractical and ill-advised to attempt to develop a one-size-fits-all response for all scenarios. However, there are some heuristics that may be applied to inform the commander of the spectrum of risks and allow them to make an informed decision based on the available evidence and intelligence. Please note the last updated date as information is rapidly changing.

15. SUBJECT TERMS
Ultraviolet Germicidal Irradiation, UVC, COVID-19

16. SECURITY CLASSIFICATION OF: U			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE	SAR	8	Doug Lewis
U	U	U			19b. TELEPHONE NUMBER *(include area code)* 937-938-3761

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

Use of Ultraviolet Germicidal Irradiation (UVGI)

for COVID-19 Decontamination Purposes

Last Updated: 03 May 2020

Purpose: This document was crafted in response to multiple inquiries regarding the use of Ultraviolet Germicidal Irradiation (UVGI) for decontamination and includes general information on the use of UVGI. More specifically, **this document includes detailed responses for two specific areas of concern that have been of interest in the DoD, decontamination and reuse of filtering facepiece (FFP) respirators, and the use of 222nm ultraviolet C (UVC) to disinfect an occupied space**. 711 HPW/RHM has developed this framework for operational/maintenance risk analysis based on the best known available information. Ultimately, the acceptance of risk rests solely with the commander who is best positioned to understand the complexities of the operational, maintenance, and mission requirements of their unit. It is impractical and ill-advised to attempt to develop a one-size-fits-all response for all scenarios. However, there are some heuristics that may be applied to inform the commander of the spectrum of risks and allow them to make an informed decision based on the available evidence and intelligence. Please note the last updated date as information is rapidly changing.

Points of Contact:

- **USAF AFMC 711HPW/RHM COVID-19 Medical Response & Integration Cell** (711HPW.RHM.MedSTCOVID-19Cell@us.af.mil)
- **Researcher:** Lawrence "Kent" Harrington, OD, PhD, DR-3, DAF (lawrence.harrington.3@us.af.mil)

1. **Summary:** Ultraviolet Germicidal Irradiation (UVGI), when used appropriately, can be an appropriate means of disinfecting air and/or surfaces. For a detailed perspective on appropriate considerations, please consult the Illumination Engineering Society Report: Germicidal Ultraviolet (GUV) FAQs. Using UVGI for FFP respirator decontamination & reuse is not standard-of-care and should only be used in a crisis situation after other preferred options are exhausted. Similarly, the use of UVC devices as a disinfection method does not appear to have enough data and scientific evidence to confirm it's safe to use in spaces occupied by humans.

2. ***General Guidance on the Use of UVGI for Decontamination Practices***

   Many general guidelines and perspectives on the use of UV radiation are available online, but among the most respected compilation of UV decontamination information can be found in the Illumination Engineering Society FAQ on Germicidal Ultraviolet (GUV)
   Illuminating Engineering Society (IES) Committee Report: Germicidal Ultraviolet (GUV) – Frequently Asked Questions; IES CR-2-20-V1; 15 April 2020; ISBN 978-0-87995-389-8

   This document covers a wide range of topics including different types of UV light and their relative efficacy of germicidal action, as well as, their human health hazards and what needs to be taken into

consideration for safe and effective use. There are specific discussions on topics that have been under consideration in the DoD including: area decontamination, HVAC decontamination and hand-held UV wands.

While the literature supports the use of UV radiation for germicidal activity in some situations, there are important limitations and considerations to ensure the safety and efficacy of any potential UV based decontamination approach.

2.1. Application of UVGI for the Decontamination & Reuse of Filtering Facepiece (FFP) Respirators

2.1.1. *Background*: In response to the shortage of FFP respirators, the Centers for Disease Control and Prevention (CDC) has published guidance on the extended Use & Limited Reuse of FFP respirators. Although disposable FFP respirators are not designed for decontamination & reuse, the CDC acknowledges that under crisis situations, decontamination of FFP respirators may need to be considered. The CDC preferred method for respirator decontamination is 5-days of storage in a breathable paper bag, with special handling procedures for reuse. If the 5-day storage decontamination strategy is not viable, CDC acknowledges three alternative decontamination methods; UVGI, vaporous hydrogen peroxide, and moist heat. The FDA has provided Emergency Use Authorizations (EUAs) for several vaporous hydrogen peroxide systems, however no EUAs have been provided for UVGI or moist heat. The University of Nebraska Medical Center (UNMC), a well-known authority on management of infectious diseases, recently published a procedure for using UVGI for disinfection of disposable FFP respirators. The Brooke Army Medical Center (BAMC) recently implemented a UVGI disinfection program based on the UNMC procedure. Other military medical organizations are considering following the UNMC and BAMC example and have requested information from the 711th Human Performance Wing (HPW) Warfighter Medical Optimization Division (RHM) on UVGI.

2.1.2. The decontamination and reuse of FFP respirators is not standard-of-care and should only be implemented in crisis situations. **CDC guidelines and FDA EUA for COVID-19, appear to prioritize methods for managing scarce respirators in descending order: Extended Use & Limited Reuse, 5-day Storage, and Non-NIOSH Approved FFP respirators with FDA EUA, vaporous hydrogen peroxide with FDA EUA, and finally UVGI or moist heat processes.** In a crisis, UVGI may be useful in decontamination & reuse of respirators, but health care providers should assume that decontamination was incomplete and handle the respirator accordingly. Opportunities for the 711HPW/RHM to help military medical facilities implement impromptu UVGI procedures include improved methods for monitoring UVGI irradiance (UVC dose), serving as a consultant for purchasing and off-label use of UVGI devices.

2.1.3. UVGI has been repeatedly proposed as an inexpensive and effective method for disinfection of FFP respirators. It is a well-established procedure used in agriculture, food processing, water treatment and a variety of other commercial applications. UVGI is commonly used in medical practice in conjunction with other disinfection methods. **UVGI is not routinely used as the sole method of medical disinfection due to difficulty in**

characterizing the UVGI system performance and therefore the inability to ensure a decontamination dose of UVC light reaches all pathogen deposits. The enthusiasm for using UVGI for the decontamination of FFP respirators should be tempered by obstacles to establishing a practical medical decontamination system.

2.1.4. Out of necessity, medical groups may decide to set up impromptu UVGI systems. For example, biosafety cabinets with UVGI capability may be used to decontaminate respirators. UNMC and BAMC have repurposed room decontamination systems for FFP respirator decontamination. A severe limitation of these ad-hoc systems is the lack of spatial and spectral characterization of the UVC energy distribution; they typically have complex spatial characteristics. The respirator is also complex in both shape and texture. **The UVC dose inevitably varies across the surface contours of the respirator. Consequently, the duration of exposure required to achieve effective decontamination is difficult to determine.** To optimize a UVGI system for high volume respirator decontamination requires an expert in non-imaging light systems which includes knowledge of: extended light sources, light falling on oblique surfaces, non-axial optical elements, spectral emission, spectral reflectance, spectral absorption and radiometry instruments. UVGI systems designed for room decontamination are not optimized for FFP respirator decontamination and are best used for their intended purpose.

2.1.5. UVGI decontamination & reuse of FFP respirators incurs significant labor cost. The respirators need to be inspected before and after UVGI treatment for soiling and damage. They have to be labeled with the name of the healthcare provider and the number of times it has been decontaminated. The respirators have to be properly handled when transferring in and out of the UVGI system, as well as transported safely to and from the UVGI facility. Tracking has to be accomplished to return the mostly clean respirator to the correct healthcare provider or to discard when the maximum number of decontamination cycles is reached.

2.1.6. UVGI exposes additional workers to contaminated FPP respirators. To ensure that the FFP respirator receives the desired dose of UVC, an operator has to position the respirator correctly in the UVGI system. In the UNMC system the operator has to hang the respirator on a wire using a clothespin. Note that the clothespin will completely block the UVC treatment at points of contact and will shadow the areas adjacent. Blocking/shadowing is a potential problem for any system that does not position the FFP respirators using a UVC transparent fixture. Risk of exposure to additional personnel is a significant disadvantage for UVGI relative to 5-day storage, and use of Non-NIOSH Approved FFP Respirators with FDA EUA.

2.1.7. UVGI is not mature enough to select as the sole method for medical decontamination; standards are not established and the research for building consensus is not in place. Medical UVGI experiments may lack rigor in their radiometry methods. Information on spectral characteristics of the lamp, the reflectors/defusers, the radiometer or the spectral sensitivity of the pathogen tends to be sparse. Basically, most systems used in UVGI experiments are not well calibrated resulting in poor knowledge of the relationship between light energy and the measured reduction in virus. Irradiance of one joule per centimeter squared (1 J/cm^2) is commonly mentioned in journal articles as being sufficient to kill pathogens, however UNMC picked a significantly lower irradiance for their system.

2.1.8. The 711th HPW has resources, light experts and light characterization equipment that could potentially be useful in establishing a UVGI capability for FFP respirators. Caution is warranted, most of the Wing's expertise exists in lasers and imaging systems, skill sets that only partially overlap with the illumination engineering expertise required to optimize a UVGI system. Developing a UVGI for FFP respirator capability from scratch would be risky and time consuming, fortunately significant commercial UVGI expertise exists for other applications. Building on existing commercial capability would increase the probability of success for any projects under consideration.

i. In this current crisis, where UVGI equipment is being repurposed, it would be very helpful to provide an easy way to monitor system performance to guide both operations and maintenance related decision making. Relevant issues to monitoring include respirator placement, exposure time and bulb replacement. UV radiometry equipment is difficult to use in a reproducible manner. Simple UV test cards, which could be placed at the design respirator location and which could provide a yes/no signal on decontamination would be highly desirable. Commercially available kits might meet this need; however they should provide data on the spectral or irradiance characteristics of the material. 711th HPW personnel could characterize the performance of the cards and, if appropriate, provide instructions on how to use them to verify the performance of UVGI for FFP respirator decontamination.

ii. 711th HPW experts could facilitate the purchase, installation and qualification of a commercial UVGI system for high volume, small item decontamination. There are commercial systems designed for applications like fresh fruit or food packaging decontamination that would take up less room than the UNMC and BAMC systems and provide higher, more uniform UV-C exposure. Ideally the vendor would install and provide training for the system.

2.2. Use of UVGI (222nm UVC) to decontaminate an occupied room

2.2.1. *Background*: In response to the COVID-19 pandemic and the potential for asymptomatic personnel to unknowingly spread the virus in workspaces, a Tiger Team was established to ensure protection of Sensitive Compartmented Information Facilities (SCIFs) from COVID-19. A commercial vendor presented the team with a device that uses UVC (222nm) disinfection as a countermeasure for infectious disease and pathogens in occupied spaces. The Tiger Team has requested information from the 711th HPW/RHM on the use of UVGI, particularly this device, in occupied workplaces.

2.2.2. Directed UVC is not a currently accepted application, particularly in occupied spaces due to the harmful effects of UVGI; proper precautions are required to avoid UVGI exposure to skin or eyes. Decontamination of an occupied room is not the appropriate place for rolling

out a new UVC decontamination process, particularly when other well-established disinfection methods, including UVC methods described in the attachment, may work as well or better than the proposed 222nm approach.

2.2.3. Things to keep in mind regarding UVGI technology:

i. UVC does not occur naturally in our environment. We have no history of long term human exposure to UVC, of any wavelength, to draw on.

ii. It's suspected that UVC is blocked by the superficial layers of the skin and therefore does not contribute to skin cancer, but that is impossible to prove (reference item 1).

iii. UVC lamps are marked with peak wavelength, all non-laser sources (and some laser sources) produce energy at other wavelengths if not heavily filtered.

iv. 222nm is not normally used in UVGI because it creates ozone.

v. Upper Room UVC is routinely used in rooms occupied by a patient with active respiratory disease, it has not been used to prevent transmission by unknown carriers.

vi. It's suspected that UVC decontamination of surfaces works better in the lab than in public spaces.

2.2.4. Precautions currently used to reduce risk are:

i. Question-based screening before entering a facility,

ii. Temperature scans,

iii. Regular cleaning of frequently touched surfaces,

iv. Social distancing,

v. Masks/face coverings,

vi. Minimize time in the SCIF, minimize the number of people.

3. ***Conclusions*****:**

3.1. While UVGI, when used appropriately, can be an appropriate means of decontamination, UVGI for FFP respirator decontamination & reuse is not standard-of-care and should only be used in a crisis situation after other preferred options are exhausted.

3.2. The CDC recognizes that decontamination & reuse of FFP may be necessary, but prefers 5-day storage over other decontamination methods. Commercial UVGI systems exist that would provide better performance that the impromptu systems currently being used, but availability of all UVGI equipment is limited and companies may not be willing to install their systems in medical facilities for off-label applications. 711HPW/RHM has resources that could help medical groups establish and sustain UVGI but the alignment between 711th HPW resources and the resources required to optimize a high volume UVGI capability are not perfect. Preferred

options for managing FFP respirator supply will likely become available before a robust UVGI capability can be established.

3.3. Regarding the use of UVC devices as a disinfection method in spaces occupied by humans, 711HPW/RHM has not seen enough data and scientific evidence to warrant its safe use. Many other methods exist that should be applied as precautions before the use of UVC in occupied spaces.

4. ***Research Efforts:*** The 711HPW/RHM team is currently working on research studies for aircraft decontamination that seek to better understand the appropriate time and temperature parameters to be used for decontamination of aircrafts potentially contaminated with COVID-19. Additional studies also underway in RHM seek to better understand airflow dynamics within an aircraft to better understand the risk of residual of infection from lingering virus in the air.

5. References:

Center for Disease Control. Decontamination and Reuse of Filtering Facepiece Respirators. https://www.cdc.gov/coronavirus/2019-ncov/hcp/ppe-strategy/decontamination-reuse-respirators.html

Center for Disease Control. Recommended Guidance for Extended Use and Limited Reuse of N95 Filtering Facepiece Respirators in Healthcare Settings https://www.cdc.gov/niosh/topics/hcwcontrols/recommendedguidanceextuse.html

Food and Drug Administration. Emergency Use Authorizations. https://www.fda.gov/medical-devices/emergency-situations-medical-devices/emergency-use-authorizations

Illuminating Engineering Society (IES) Committee Report: Germicidal Ultraviolet (GUV) – Frequently Asked Questions; IES CR-2-20-V1; 15 April 2020; ISBN 978-0-87995-389-8

Lowe, John J., et al. "N95 filtering facepiece respirator ultraviolet germicidal irradiation (UVGI) process for decontamination and reuse." *Nebraska Medicine* 10 (2020).

6. Disclaimer:

This document was crafted in response to multiple inquiries regarding the use of Germicidal UV Irradiation (UVGI) for decontamination and includes a recommendation for general information on the use of UVGI. More specifically, this document includes detailed responses for a two specific areas of concern that have been of interest in the DoD, decontamination and reuse of filtering facepiece (FFP) respirators and decontamination and the use of 222nm ultraviolet C (UVC) in an occupied space.

To assist those with a need for information on the use of UVGI, we at USAF AFMC 711HPW/RHM are providing this standard response document to represent our interpretation of the state of the science and key considerations to keep in mind in the evaluation of UVGI techniques.

We believe it is imperative that USAF AFMC 711HPW/RHM supports its customers and the broader Air Force during this unprecedented time caused by COVID-19 by providing balanced, thoughtful scientific data for discussion. We aim to provide the above data and discussion for the consideration of the medical teams and operational commanders making recommendations and guidelines.

This document was specifically crafted to assist in understanding decontamination options with the intent to provide information only, not to share opinions or recommendations. This document is intended, and should be used for, this purpose and no other. This documentation is not intended to be used as operational guidance on its own.

Finally, the information provided is not intended to address specific patient care or to provide advice about the transmission of contagious illness. Procedures and equipment required to reduce the risk of transmission of contagious illness to crew and ground support personnel are outside of the scope of what has been provided. This document is for general informational purposes only, and not to provide specialized guidance.

Content in this document is intended to provide guidance on this specific topic and does not represent a position on policy or endorse a specific direction in policy. These are the scientific opinions and literature reviews constructed by 711 HPW/RHM scientists. If there are any questions related to what is contained in the document, please direct them towards the RHM COVID-19 Medical Response and Integration Cell: 711HPW.RHM.MedSTCOVID-19Cell@us.af.mil.