International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

CIE Position Statement on Ultraviolet (UV) Radiation to Manage the Risk of COVID-19 Transmission

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Introduction

The coronavirus disease (COVID-19) pandemic has accelerated the search for environmental controls to contain or mitigate the spread of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) responsible for the disease. SARS-CoV-2 is usually transmitted from person to person by contact with large respiratory droplets, either directly or by touching virus-contaminated surfaces (also denoted as fomites) and subsequently touching the eyes, nose or mouth. Importantly, there is growing evidence of virus transmission via the airborne route as the large respiratory droplets dry out and form droplet nuclei which can remain airborne for several hours. Depending on the nature of the surface and environmental factors, fomites can remain infectious for several days (van Doremalen, 2020).

The use of germicidal UV radiation (GUV) is an important environmental intervention which can reduce both contact spread and airborne transmission of infectious agents (like bacteria and viruses). GUV within the UV–C range (200 nm-280 nm), primarily 254 nm, has been used successfully and safely for over 70 years. However, GUV must be knowledgably applied with appropriate attention to dose and safety. Inappropriate GUV application can present human health and safety issues and produce insufficient deactivation of infectious agents. Application in the home is not advisable and GUV should never be used to disinfect the skin, except when clinically justified.

What is GUV?

Ultraviolet radiation is that part of the optical radiation spectrum that has more energy (shorter wavelengths) than visible radiation, which we experience as light. GUV is ultraviolet radiation that is used for germicidal purposes.

Based on the biological impact of ultraviolet radiation on biological materials, the ultraviolet spectrum is divided into regions: UV-A is defined by CIE as radiation in the wavelength range between 315 nm and 400 nm; UV-B is radiation in the wavelength range between 280 nm and 315 nm; and the UV–C wavelength range is between 100 nm and 280 nm. The UV–C part of the UV spectrum has the highest energy. Whilst it is possible to damage some microorganisms and viruses with most of the ultraviolet radiation spectrum, UV–C is the most effective and hence UV–C is most commonly used as GUV.

The radiant exposure required for the deactivation of an infectious agent by 90 % (in air or on a surface) depends on the environmental conditions (such as relative humidity) and the kind of infectious agent. It typically ranges between 20 J/m2 and 200 J/m2 for mercury lamps predominantly emitting radiation at 254 nm (CIE, 2003). Previously, GUV of 254 nm has been shown to be effective in disinfecting surfaces contaminated with the Ebola virus (Sagripanti and Lytle, 2011; Jinadatha et al., 2015; Tomas et al., 2015). Other studies have demonstrated

the effectiveness of GUV during an influenza outbreak in the Livermore Veterans Hospital (Jordan, 1961). However, despite ongoing research, at present there is no published data on the effectivity of GUV against SARS-CoV-2.

Applying GUV for disinfection

UV–C has been used successfully for water disinfection for many years. Moreover, UV–C disinfection is routinely incorporated into air handling units to manage the build-up of biofilms and to disinfect air (CIE, 2003).

Until the introduction of polymer materials in healthcare settings and the availability of antibiotics and vaccines, UV–C sources were commonly used in several countries to sterilize operating theatres and other rooms overnight. Recently, there has been a resurgence of interest in the use of whole room UV–C exposure devices for healthcare environments intended to disinfect the air and accessible surfaces in the room. Such devices can either be placed in a specific room location for a period of time, or they can be robotic units that move around the environment to minimize shadow effects. For surface disinfection, in addition to the option to place a UV–C source in the room, it is possible to place a UV–C source close to a surface.

Limited use of UV–C for disinfection of personal protective equipment during pandemics has been explored in some countries (Jinadatha et al., 2015; Nemeth et al., 2020).

There is growing evidence that the use of UV–C as an adjunct to standard manual cleaning in hospitals can be effective in practice, although more specific application guidelines still need to be developed as well as standard testing procedures.

Upper air disinfection UV–C sources are usually mounted above head-height in rooms and operate continuously to disinfect circulating air. Such sources have been successfully deployed to limit the transmission of tuberculosis (Mphaphlele, 2015; Escombe et al., 2009; DHHS, 2009). Based on a systematic review of the literature, the World Health Organization (WHO) recommended the use of upper room GUV as a means for tuberculosis infection prevention and control (WHO, 2019).

Some laboratory studies have found that the effectivity of upper-air UV–C disinfection depends on the relative humidity, temperature conditions and air circulation (Ko et al., 2000; Peccia et al., 2001). Escombe et al. (2009) studied upper room GUV in a non-air-conditioned hospital ward in Lima, Peru, and found a marked reduction in the risk of transmission of airborne tuberculosis, despite the high relative humidity of 77 %.

Risks when using UV–C

Most people do not get exposed to UV–C naturally: UV–C from the sun is primarily filtered by the atmosphere, even at high altitudes (Piazena and Häder, 2009). Human exposure to UV–C typically arises from artificial sources. UV–C only penetrates the outermost layers of the skin and hardly reaches the basal layer of the epidermis, neither does it penetrate deeper than the surface layer of the cornea of the eye. Exposure of the eye to UV–C can result in photokeratitis, a very painful condition that feels as if sand has been rubbed onto the eye. Photokeratitis symptoms take up to 24 hours after the exposure to develop and require about another 24 hours for them to subside.

When the skin gets exposed to high levels of UV–C, erythema (a skin reddening similar to sunburn) can develop (ISO/CIE, 2019). Usually erythema is less painful than the effect of UV–C on the eyes. However, the UV–C-induced erythema can be misdiagnosed as dermatitis, especially when it is not known that there was a recent UV–C exposure history. There is some evidence that repeated exposure of the skin to UV–C levels that cause erythema may compromise the body's immune system (Gläser et al., 2009).

Ultraviolet radiation is generally considered to be carcinogenic (ISO/CIE, 2016), however, there is no evidence that UV–C alone causes cancer in humans. The Technical Report CIE187:2010 (CIE, 2010) discusses the question and concludes: "while the UV radiation from low- pressure mercury UVGI[1] lamps has been identified as a potential carcinogen, the relative risk of skin cancer is significantly less than the risk from other sources (such as the sun) to which a worker will be routinely exposed. UV germicidal irradiation can be safely and effectively used for upper-air disinfection without a significant risk of long-term delayed effects such as skin cancer."

Guidance for occupational exposure to UV radiation including UV–C radiation has been provided by the International Commission on Non-Ionizing Radiation Protection (ICNIRP, 2004): UV radiant exposure upon unprotected eyes/skin should not exceed 30 J/m^2 for radiation of 270 nm, the peak wavelength of the spectral weighting function for actinic UV hazard for skin and eye. As the hazard effect of UV radiation depends on wavelength, the maximum exposure limit for radiation of wavelength 254 nm is 60 J/m^2. For radiation of 222 nm the maximum (actinic UV hazard) exposure limit is even higher, around 240 J/m^2. This wavelength has been studied for germicidal purposes in (Buonanno et al., 2017; Welch et al., 2018; Narita et al., 2018; Taylor et al., 2020; Yamano et al., 2020). The preceding (daily) UV exposure limits are given in the

[1] UVGI is the acronym of "ultraviolet germicidal irradiation".

IEC/CIE standard for the photobiological safety of products (IEC/CIE, 2006).

Typical UV–C sources often also emit radiation that includes various wavelengths outside the UV–C range. Some UV–C products may additionally emit UV-B or UV-A, and some UV disinfection sources declared as UV–C sources may not even emit UV–C. As the exposure to UV from such products may increase the risk of skin cancer, protective measures have to be taken to minimize this risk. In normal use, UV sources secured inside ductwork for recirculated air or used for water sterilization should not present a risk of exposure to people. When working in a UV-irradiated zone, workers shall wear personal protective equipment such as industrial clothing (e.g. heavy fabric), and industrial face protection (e.g. face shields) (ICNIRP, 2010). Full-face respirators (CIE, 2006) and hand protection by disposable gloves (CIE, 2007) are also protective against UV.

Measurement of UV–C

In-situ measurement of UV–C is usually performed using handheld UV–C radiometers. Ideally, any radiometer should be calibrated by a laboratory that is accredited to ISO/IEC17025 (ISO/IEC, 2015), so that the calibration is traceable to the International System of Units (SI) (BIPM, 2019a; BIPM, 2019b). Moreover, it is important to check the calibration report and apply any correction factors which are contained within the report when using the instrument. The calibration report is usually only valid for the UV–C source used in the calibration; significant errors may result when measuring other source types with the instrument. Most instrument calibrations are typically done using the 254 nm emission line of a low-pressure mercury source. If the calibrated instrument is then used to measure a UV source with a wavelength (range) that is significantly different from 254 nm, this may result in spectral mismatch errors of tens of per cent. Some UV–C radiometers can be calibrated to account for wavelengths other than 254 nm, for example for use with UV LED sources or excimer lamps.

When a UV radiometer is calibrated, it is best practice for the calibration laboratory to ask the user what type of source will be evaluated with the instrument, so that ideally the instrument will be calibrated using a source with a similar spectral composition as the sources to be measured by the user, in order to reduce these spectral mismatch errors. CIE220:2016 (CIE, 2016) provides guidance for characterization and calibration of UV radiometers. Further information about the measurement of optical radiation hazards is provided in (ICNIRP/CIE, 1998). At present, CIE and ICNIRP are organizing an online tutorial on the measurement of optical radiation and its effects on photobiological systems (CIE/ICNIRP, 2020).

Consumer products

As the present COVID-19 pandemic spreads, many UV–C products promising efficient disinfection of surfaces and air are being put on the market. Specific guidance on the safety of consumer products is the responsibility of international organizations such as the International Electrotechnical Commission (IEC), and is not provided by CIE. As such, this Position Statement only covers the wider issue of the safe use and application of UV radiation for germicidal disinfection. Products available to consumers tend to be marketed as handheld devices. CIE is concerned that users of such devices may be exposed to harmful amounts of UV–C. Moreover, consumers may use/handle UV products inappropriately (and therefore not achieve effective disinfection) or they might be buying products that do not actually emit UV–C.

Summary recommendations

Products that emit UV–C are extremely useful in disinfection of air and surfaces or sterilization of water. CIE and WHO warn against the use of UV disinfection lamps to disinfect hands or any other area of skin (WHO, 2020), unless clinically justified. UV–C can be very hazardous to humans and animals and therefore can only be used in properly constructed products that meet safety regulations, or in very controlled circumstances where safety is taken into account as the first priority, ensuring that the limits of exposure as specified in ICNIRP (2004) and IEC/CIE (2006) are not exceeded. For proper UV assessment and risk management, appropriate UV measurements are essential.

References

BIPM (2019a) *The International System of Units (SI), 9th Edition.*
Downloadable at https://www.bipm.org/utils/common/pdf/si-brochure/SI-Brochure-9-EN.pdf

BIPM (2019b) *The International System of Units (SI), 9th Edition – Appendix 3: Units for photochemical and photobiological quantities.*
Downloadable at https://www.bipm.org/utils/common/pdf/si-brochure/SI-Brochure-9-App3- EN.pdf, accessed 2020–04–24.

Buonanno, M., Ponnaiya, B., Welch, D., Stanislauskas, M., Randers-Pehrson, G., Smilenov, L., Lowy, F.D., Owens, D.M. and Brenner, D.J. (2017) Germicidal Efficacy and Mammalian Skin Safety of 222-nm UV Light. *Radiat Res* 187(4): 483–491. DOI:10.1667/RR0010CC.1

CIE (2003) CIE155:2003 *Ultraviolet Air Disinfection*. Freely available at http://cie.co.at/news/cie-releases-two-key-publications-uv-disinfection[2]

CIE (2006) CIE172:2006 *UV protection and clothing.*

CIE (2007) CIE181:2007 *Hand protection by disposable gloves against occupational UV exposure.*

CIE (2010) CIE187:2010 *UV–C photocarcinogenesis risks from germicidal lamps*.

Freely available at http://cie.co.at/news/cie-releases-two-key-publications-uv-disinfection[2]

CIE (2016) CIE220:2016 *Characterization and Calibration Methods of UV Radiometers.*

CIE/ICNIRP (2020) CIE/ICNIRP *Online Tutorial on the Measurement of Optical Radiation and its Effects on Photobiological Systems, August 25, 2020 to August 27, 2020*. http://cie.co.at/news/cieicnirp-online-tutorial-measurement-optical-radiation-and-its-effects-photobiological-systems, accessed 2020–04–24.

DHHS (2009) *Environmental Control for Tuberculosis: Basic Upper-Room Ultraviolet Germicidal Irradiation Guidelines for Healthcare Settings*, DHHS (NIOSH) Publication Number 2009–105, https://www.cdc.gov/niosh/docs/2009–105/default.html, accessed 2020-04–25.

Escombe, A.R., Moore, D.A., Gilman, R.H., Navincopa, M., Ticona, E., Mitchell, B., Noakes, C., Martínez, C., Sheen, P., Ramirez, R., Quino, W., Gonzalez, A., Friedland, J.S., Evans,

C.A. (2009) *Upper-room ultraviolet light and negative air ionization to prevent tuberculosis transmission*. *PLoS Med*. 6(3): e43. DOI: 10.1371/journal.pmed.1000043.

Gläser, R., Navid, F., Schuller, W., Jantschitsch, C., Harder, J., Schröder, J.M., Schwarz, A., Schwarz, T. (2009) UV-B radiation induces the expression of antimicrobial peptides in human keratinocytes in vitro and in vivo. *Journal of Allergy and Clinical Immunology* 123(5): 1117–1123. DOI: 10.1016/j.jaci.2009.01.043

ICNIRP (2004) ICNIRP Guidelines – On limits of exposure to ultraviolet radiation of wavelengths between 180 nm and 400 nm (incoherent optical radiation), *Health Physics* 87(2):171–186; 2004.

[2] Limited free access until 2020–06–25.

Available at http://www.icnirp.org

ICNIRP (2010) ICNIRP Statement – Protection of workers against ultraviolet radiation, *Health Physics* 99(1):66-87; DOI: 10.1097/HP.0b013e3181d85908

Available at http://www.icnirp.org

ICNIRP/CIE (1998) ICNIRP 6/98 / CIE x016–1998. *Measurement of Optical Radiation Hazards.*

IEC/CIE (2006) IEC62471:2006/CIE S009:2002 *Photobiological safety of lamps and lamp systems / Sécurité photobiologique des lampes et des appareils utilisant des lampes.* (bilingual edition)

ISO/IEC (2015) ISO/IEC17025:2015 *General requirements for the competence of testing and calibration laboratories.*

ISO/CIE (2016) ISO/CIE28077:2016(E) *Photocarcinogenesis action spectrum (non- melanoma skin cancers).*

ISO/CIE (2019) ISO/CIE17166:2019(E) *Erythema reference action spectrum and standard erythema dose.*

Jinadatha, C., Simmons, S., Dale, C., Ganachari-Mallappa, N., Villamaria, F.C., Goulding, N., Tanner, B., Stachowiak, J., Stibich, M. (2015) Disinfecting personal protective equipment with pulsed xenon ultraviolet as a risk mitigation strategy for health care workers. *Am J Infect Control* 43(4): 412–414. DOI: 10.1016/j.ajic.2015.01.013

Jordan, W.S. (1961) The Mechanism of Spread of Asian Influenza, *Am Rev Resp Dis.*

Volume 83, Issue 2P2, Pages 29–40. DOI: 10.1164/arrd.1961.83.2P2.29

Ko, G., First, M.W., Burge, H.A. (2000) Influence of relative humidity on particle size and UV sensitivity of Serratia marcescens and Mycobacterium bovis BCG aerosols. *Tubercle and Lung Disease*. Volume 80, Issues 4–5, Pages 217–228.
DOI: 10.1054/tuld.2000.0249

Mphaphlele, M. (2015) Institutional Tuberculosis Transmission. Controlled Trial of Upper Room Ultraviolet Air Disinfection: A Basis for New Dosing Guidelines*. Am J Respir Crit Care Med*. 192(4):477–84. DOI: 10.1164/rccm.201501–0060OC

Narita, K., Asano, K., Morimoto, Y., Igarashi, T., Hamblin, M.R., Dai, T. and Nakane, A. (2018) Disinfection and healing effects of 222-nm UVC light on methicillin-resistant Staphylococcus aureus infection in mouse wounds. *Journal of Photochemistry and Photobiology B: Biology* 178: 10–18. DOI: 10.1016/j.jphotobiol.2017.10.030

Nemeth, C., D. Laufersweiler, E. Polander, C. Orvis, D. Harnish, S.E. Morgan, M. O'Connor,

S. Hymes, S. Nachman and B. Heimbuch (2020). "Preparing for an Influenza Pandemic: Hospital Acceptance Study of Filtering Facepiece Respirator Decontamination Using Ultraviolet

Germicidal Irradiation." J Patient Saf. DOI 10.1097/PTS.0000000000000600.

Peccia, J., Werth, H.M., Miller, S., Hernandez, M. (2001) Effects of Relative Humidity on the Ultraviolet Induced Inactivation of Airborne Bacteria, *Aerosol Science and Technology*, Volume 35, Issue 3, DOI: 10.1080/02786820152546770

Piazena, H. and Häder, D.-P. (2009) Solar UV-B and UV-A irradiance in arid high-mountain regions: Measurements on the island of Tenerife as compared to previous tropical Andes data. *Journal of Geophysical Research: Biogeosciences.* 114(G4).?
DOI: 10.1029/2008JG000820

Sagripanti, J.-L. and Lytle, C.D. (2011) Sensitivity to ultraviolet radiation of Lassa, vaccinia, and Ebola viruses dried on surfaces. *Archives of Virology* 156(3): 489–494.

DOI: 10.1007/s00705–010–0847–1

Taylor, W., Camilleri, E., Craft, D.L., Korza, G., Granados, M.R., Peterson, J., Szczpaniak, R., Weller, S.K., Moeller, R., Douki, T., Mok, W.W.K. and Setlow, P. (2020) DNA Damage Kills Bacterial Spores and Cells Exposed to 222-Nanometer UV Radiation. *Applied and Environmental Microbiology* 86(8): e03039–03019. DOI:10.1128/aem.03039–19

Tomas, M.E., Cadnum, J.L., Jencson, A., Donskey, C.J. (2015) The Ebola disinfection booth: evaluation of an enclosed ultraviolet light booth for disinfection of contaminated personal protective equipment prior to removal. *Infect Control Hosp Epidemiol.* 36(10): 1226–1228.
DOI: 10.1017/ice.2015.166

van Doremalen, N., Bushmaker, T., Morris, D.H., Holbrook, M.G., Gamble, A., Williamson, B.N., Tamin, A., Harcourt, J.L., Thornburg, N.J., Gerber, S.I., Lloyd-Smith, J.O., de Wit, E.,

Munster, V.J. (2020) Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS- CoV-1. *N Engl J Med.* 382: 1564–1567. DOI: 10.1056/NEJMc2004973

Welch, D., Buonanno, M., Grilj, V., Shuryak, I., Crickmore, C., Bigelow, A.W., Randers- Pehrson, G., Johnson, G.W. and Brenner, D.J. (2018) Far-UVC light: A new tool to control the spread of airborne-mediated microbial diseases. *Scientific Reports* 8(1): 2752.
DOI: 10.1038/s41598–018–21058-w

WHO (2019) *WHO guidelines on tuberculosis infection prevention and control*. 2019 update. Geneva: World Health Organization.

WHO (2020) https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public/myth-busters, accessed 2020–04–22.

Yamano, N., Kunisada, M., Kaidzu, S., Sugihara, K., Nishiaki-Sawada, A., Ohashi, H., Yoshioka, A., Igarashi, T., Ohira, A., Tanito, M. and Nishigori, C. (2020) Long-term effects of 222 nm ultraviolet radiation C sterilizing lamps on mice susceptible to ultraviolet radiation.

Photochemistry and Photobiology. DOI: 10.1111/php.13269

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