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Kevin W. Houser

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EDITORIAL

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The COVID-19 pandemic has generated interest in the potential of ultraviolet (UV) radiation to disinfect air and surfaces. In response, the IES Photobiology Committee published a freely available report about germicidal ultraviolet radiation (IES 2020). As an even-handed treatment of UV radiation's potential and limitations, the report is a welcomed counter-point to information appearing in social media feeds, the popular press, and in shady sales literature. Below are ten facts about UV radiation and COVID-19.

(1) The International Commission on Illumination subdivides the UV spectrum into three bands based on wavelength (CIE 2020). UV-C radiation is from 100 to 280 nm, UV-B from 280– 315 nm, and UV-A from 315 to 400 nm. UV-C is most effective for viral sterilization and is the primary tool for disinfecting air and surfaces. Germicidal ultraviolet radiation (GUV) and UV germicidal irradiation (UVGI) from electric light sources are almost always based on UV-C radiation.

(2) The SARS-CoV-2 virus can be rendered noninfectious with the application of UV-C radiation. This is because UV-C radiation damages its RNA sequence, breaking its bonds in a way that stops its ability to replicate. Colloquially, it may be said that UV-C radiation "kills" the virus that causes COVID-19.

(3) Though sunlight does not contain UV-C, if conditions are right it contains enough UV-B to inactivate the SARS-CoV-2 virus. When daylight has a UV index of 10, which could occur on a clear summer day when the sun is high in the sky, it may take an hour or so to achieve 99.9% inactivation. Sunlight is not a panacea because the SARS-CoV-2 virus remains viable in respirated droplets and on surfaces for up to an hour even when exposed to intense direct sunlight.

(4) If the type of UV radiation under discussion is harmful to bacteria and viruses, then it is also harmful to human skin and eyes. UV-C radiation should not be used to disinfect the hands or other body parts. Care should be taken to avoid skin and eye exposure.

(5) The reverse is also true. Sources that produce UV-A, including blacklights and UV insect traps, are not appreciably harmful to people or the SARS-CoV-2 virus.

(6) Viral inactivation from UV-C radiation can be considered in log steps. One log step represents 90% inactivation, 2 log steps 99% inactivation, 3 log steps 99.9% inactivation, and so on. Reduction by each log step requires a doubling of the dose of UV-C radiation.

(7) To reach the same degree of viral inactivation, intensity and duration of exposure are tradable quantities. For example, if intensity is doubled, exposure time can be halved. Quantitatively, dose ($\mu J/cm^2$) = UV-C fluence ($\mu W/cm^2$) × duration of exposure (s).

(8) LED emitters that produce UV-C radiation are not widely available. Most of the UV LEDs that are commercially available today emit longer-wavelength UV, which is less effective for rendering viruses as noninfectious.

(9) A low-pressure mercury discharge emits a significant fraction of its radiation at 253.7 nm. Low pressure mercury lamps are by far the most common type of UV-C source. This is not likely to change in the near term.

(10) In healthcare settings, upper-air UV-C radiation systems should be expected to be at least partially effective for reducing viral transmission. In these systems, a luminaire containing a source that generates UV-C radiation is mounted above

standing head-height and the UV-C radiation is directed toward the room's upper air. These systems can achieve a high level of equivalent air-changes per hour.

When properly used (e.g., in unoccupied spaces or at heights that are out of reach and out of sight) UV-C can be employed to lessen the spread of COVID-19 by inactivating the SARS-CoV-2 virus in the air and on surfaces, including sterilization of personal protective equipment. This is especially important in settings where healthcare professionals are at risk. It should be emphasized that UV-C is dangerous and is not appropriate in residential settings.

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Kevin W. Houser
School of Civil and Construction Engineering, Oregon State University, Corvallis, Oregon, USA
kevin.houser@oregonstate.edu http://orcid.org/0000-0001-6097-1560