TIP NO. 98-128-1120

CONSIDERATIONS FOR THE USE OF ULTRAVIOLET GERMICIDAL IRRADIATION (UVGI)

ULTRAVIOLET GERMICIDAL IRRADIATION

Ultraviolet Germicidal Irradiation (UVGI) may be used as a supplemental engineering control for air purification, but should not replace existing, sufficient ventilation or filtration systems. UVGI refers to ultraviolet (UV) wavelengths in the UVC range 200 nanometers (nm) to 280 nm[1] that are generated by germicidal lamps to inactivate microorganisms. UVGI radiant energy damages nucleic acids (DNA and RNA) by causing mutations that prevent replication,[2] rendering them unable to cause infection.[3] The UVGI systems themselves are not filters and do not remove infectious organisms from the air. Despite UVGI treatment, inactivated particles will persist in the airstream and these may potentially cause negative response if distributed by the ventilation system (e.g., dead fungal spores).[4] Filtration is therefore still necessary to capture airborne particles. Additional information on the effectiveness of UVGI for air and surface disinfection is available from the Illuminating Engineering Society (IES) CR-2-20-V1, *Germicidal Ultraviolet (GUV) – Frequently Asked Questions.*[2]

- The U.S. Centers for Disease Control and Prevention (CDC) states in their Guidelines for Preventing the Transmission of *Mycobacterium tuberculosis* in Health-Care Settings[5]: "UVGI is an air-cleaning technology that can be used in a room or corridor to irradiate the air in the upper portion of the room (upper-air irradiation) and is installed in a duct to irradiate air passing through the duct (duct irradiation) or incorporated into room air-recirculation units. UVGI can be used in ducts that recirculate air back into the same room or in ducts that exhaust air directly to the outside. However, UVGI should not be used in place of High Efficiency Particulate Air (HEPA) filters when discharging air from isolation booths or enclosures directly into the surrounding room or area or when discharging air from an Airborne Infectious Isolation Room into the general ventilation system."

- The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) provides the following position on filtration and air cleaning technologies: "All filtration and air-cleaning technologies should be accompanied by data documenting their performance regarding removal of contaminants; these data should be based on established industry test standards. If not available, scientifically controlled third-party evaluation and documentation should be provided."[4]

AIR-HANDLER COMPONENT SURFACE STERILIZATION VERSUS IN-DUCT SYSTEM AIRSTREAM DISINFECTION

UV systems installed in air-handling units are generally intended to control microbial growth on the coils and condensate pans and may not be suitable for airstream disinfection. These systems are *air handler component surface sterilization*[1] systems and are generally located about 18 inches from the coil and pan. *In-duct airstream disinfection*[1] UV systems are intended to destroy contaminants in the airstream as they are moving through the ventilation system. In-duct airstream disinfection systems may also provide air handler component surface sterilization if designed for this purpose. In-duct airstream disinfection UV systems are generally located parallel to the airstream, although some may be perpendicular, and are located upstream or downstream of the heating/cooling coil. Lamps located upstream are generally considered less effective for coil and pan surface sterilization but more effective and economical for airstream disinfection.[1] Systems treating the coil/drain pan are designed to deliver UV energy for a long period of time, and UV systems for airstream disinfection must be designed to deliver sufficient UV energy in a very short period of time. Both will have predetermined "dosages" (microwatts-sec/cm^2 (µW-s/cm^2)) depending on the targeted contaminant. The UV units may be operated either continuously or, in some cases, periodically.

It should be made clear prior to any purchase or installation whether the intention is to treat the coil/drain pan (*air handler component surface sterilization*), or to treat the air (*in-duct airstream disinfection*), or both, as dwell times and configurations may be different for each. Manufacturers should be willing to provide "calculations including sizing and placement diagrams, real-time kill rates per air change on the specified contaminant, and real-time microwatt intensities and end-of-lamp life intensities (after 1 or 2 years of operation)."[6] Both types of UV treatment, *air-handler component surface sterilization* and *in-duct airstream disinfection*, while potentially effective at removing pathogens from coils, drain pans, or recirculated air, do little to prevent direct person-to-person transmission of pathogens occurring within the occupied space.[2] Ultraviolet light treatment at the air handler does not eliminate the need for other infection control measures and should be accompanied by personnel actions, including but not limited to, wearing face coverings and physical distancing, and increased cleaning and disinfection measures within the occupied space. These actions, in addition to other room-based control measures, are intended to minimize person-to-person transmission.

For *in-duct airstream disinfection* UV systems, an average irradiance is 1000 to 10,000 µW/cm^7 with a minimum irradiance zone of 2 feet depending on the application; a rule of thumb is to install in a location that can provide 0.25 seconds of UV exposure (assuming 500 fpm air velocity).[1] ASHRAE states that a minimum target dose is 1500 µJ/cm.[2,8] While in-duct UVGI may have some benefit for disinfecting viruses or bacteria which may be transmitted through recirculated air (e.g., influenza or tuberculosis), upper-room UVGI may be preferable in order to effectively interrupt pathogen transmission that mainly occurs between occupants within a room.[2] Upper-room UVGI is discussed in the next section.

UPPER-AIR OR UPPER-ROOM SYSTEMS

Upper-air or upper-room UVGI is generally considered to be the most applicable type of UV use for room air disinfection. Upper-air or upper-room fixtures work by using UV energy to damage bacteria and inactivate viruses in the upper-room air; these fixtures target mixed air at approximately 7 feet or higher above the floor. It may be necessary to install ceiling fans to ensure air mixing that maximizes the performance of upper-room UVGI lamps. Upper-air UV system efficacy depends on factors such as degree of air-mixing, room air ventilation rates, room configuration, relative humidity, proper system design, installation, and maintenance, as well as the contaminant for which the system is used.[4] Equipment selection should be carefully considered. According to ASHRAE, well-designed systems generally must have an average irradiance of between 30 to 50 μW/cm^2 to be effective in inactivating airborne droplet nuclei-containing mycobacteria; this irradiance range is presumably effective against viruses as well.[1] Because upper-air UVGI systems are intended for use in occupied rooms, proper installation of the UVGI lamps is critical to ensure worker and patient safety. Stray UVC radiation reflected from upper room surfaces (e.g., wall paints and ceiling tiles) or direct UVC radiation from improperly installed UVGI lamps may pose a hazard to personnel. A risk assessment is recommended to ensure that the daily UV exposure in the work area (i.e., lower room) is within requisite limits before allowing workers or patients to resume normal activity.[9] This assessment should involve UV-C measurements using detectors that are tailored to the specific wavelengths emitted by the UVGI lamp (e.g., calibrated at 254 nm for measuring low-pressure mercury UVGI lamp hazards), as well as an assessment of the most common worker locations, activities, and exposure durations during a typical work day. This assessment should be performed by qualified personnel with experience in measuring UVGI lamp hazards (e.g., some lamp vendors, in-house personnel, or third-party measurement specialists who are experienced in UVGI lamp measurements).

For air disinfection, air changes per hour (ACH) have been used for measuring air disinfection efficacy. This is the rate of outdoor air—measured in room volume per hour—that would achieve equivalent reduction of contaminants, for example equivalent-ACH or e-ACH.[10] Odor control may be accomplished with relatively low levels of ventilation (1-2 ACH) but air disinfection may require higher rates (6-12 ACH)[2]. The CDC, for example, recommends various minimum levels of ACH for preventing transmission of tuberculosis in appropriate areas of health care settings.[5] For a room normally ventilated by 6 ACH, adding an upper-room UVGI system with proper air mixing may provide 10-20 additional e-ACH.[11]

ROOM AIR CLEANERS WITH UV

Portable room-air cleaners with HEPA filtration are designed to capture contaminants, so filters with both UVGI and HEPA capabilities may be redundant. The CDC states “the use of UV lamps and HEPA filtration in a single unit offers only minimal infection-control benefits over those provided by the use of a HEPA filter alone.”[12] If an air purifier includes a UV lamp, the US Food and Drug Administration (FDA) recommends the manufacturer evaluate the product for time, dose, and intensity with validation of cleaning and disinfection procedures.[13] Additional information on UV and portable HEPA/Ultra-Low Particulate Air (ULPA) filtration units can be

found in APHC's TIP 98-124-0820, *Considerations for the Use of Portable High Efficiency Particulate Air Filtration Units*.[14]

SURFACE DISINFECTION SYSTEMS

While UVGI is an excellent surface disinfectant, it does not penetrate surfaces and cannot disinfect soiled surfaces (disinfection kills germs on surfaces or objects). Surfaces must be in the direct "line of sight" of the UV energy. The inability of the UV radiation to reach the "nooks and crannies" of surfaces or to penetrate dust and other matter negatively impacts the effectiveness of UVGI disinfection. Therefore, UVGI is best utilized as part of a multi-tiered approach for disinfection.[9] Surfaces must be pre-cleaned prior to using UVGI regardless of the location where the UVGI unit is used, and UVGI lamps must be regularly cleaned in order to ensure effectiveness. The dose (μJ/cm^2) of UVC light needed to disinfect a surface depends on the selected target pathogen and desired disinfection level.[1] A positive aspect of mobile systems is that their mobility can expose surfaces that can't be reached by fixed UV lamp treatments. The ASHRAE recommends adopting the operational settings required to control for pathogens such as Methicillin-resistant Staphylococcus aureus (MRSA), or the intestinal bacteria *C. difficile*, which are difficult to inactivate, if the intention is to inactivate coronaviruses.[8] UV absorption varies by material, depending on its reflectivity, intensity, and radiation time. The amount of UV-C dose delivered to the intended surface can be measured and is critical to performance of surface disinfection devices. The FDA has established recommendations for the manufacturers of UV disinfecting devices, including statements regarding the time, distance, and area for which the device is effective.[13] Some UV surface disinfection systems may require connection to the internet or wireless services for remote operation. Preparation is required prior to implementation of UV systems, such as setting sensors to stop the unit if someone enters the area while the unit is running. There are quality assurance sensors and/or treatment monitors (i.e., test strips) available to ensure disinfection is completed. The units must be monitored while in use. Consideration must also be given to material degradation due to exposure to the UV energy. Note that disinfection of medical devices must comply with FDA requirements.

The germicidal effectiveness for surface disinfection is often reported in terms of "log kills" or "log reduction." For example: if a given UV dose reduces a bacteria's population down to 10% (i.e., reduces the population by one log unit), then the germicidal efficacy is "one log reduction." If a given UV dose inactivates a population down to 1% (i.e., reduce the population by two log units), then the germicidal efficacy is a "two log reduction." Reduction down to 0.1% (i.e., three log units) indicates that the germicidal efficacy is a "three log reduction," and so on.

Handheld wands for surface disinfection of surfaces should provide irradiance at a distance in front of the device (e.g., 10 mW/cm^2 at 2 cm), and the dose (irradiance x exposure time) should be at least 40 mJ/cm^2 for inactivation of viruses on flat surfaces (e.g., a handheld wand emitting at 10 mW/cm^2 at 2 cm would need to be held at 2 cm from the surface for 4 seconds in order to obtain 40 mJ/cm^2 at the surface).[2,15] However, inexperienced users may be more likely to use these devices improperly. Moving a handheld wand briefly over a surface is unlikely to provide

adequate disinfection. Even if these devices are used safely, they made provide a false impression of effective disinfection.[2]

FDA has recommended criteria for UVGI surface disinfection lamp systems which are used as medical devices. These criteria include recommended log reductions for low, intermediate, and high levels of disinfection for various microorganisms.[13] UVGI lamps which are not marketed as medical devices are regulated by the Environmental Protection Agency (EPA) as "pesticidal devices." Unlike chemical pesticides, EPA does not routinely review the safety or efficacy of pesticidal devices, and therefore UVGI lamps are not included on EPA's "List N" disinfectants for COVID-19. Companies may be subject to penalties for selling devices with false or misleading claims about efficacy or safety, and are advised to maintain records to confirm that claims made on device labels are true and not misleading.[16]

WHOLE-ROOM (BARE-LAMP) UVGI

Whole-room bare lamp UVGI systems may be used in locations such as operating rooms or special settings where viral transmission is highly likely. The UVGI system is designed to disinfect air and surfaces by directing the UV energy into the whole room, usually with suspended fixtures directing the UV energy downward. These systems require occupants to vacate the room or to have appropriate Personal Protective Equipment (PPE) to protect them from eye and skin exposure. Like other UVGI systems these systems require a direct "line of sight" in order for the UV energy to disinfect the accessible surface. This method is an adjunct to physical cleaning and requires pre-cleaning the room prior to use. Consideration also must be given to material degradation due to exposure to the UV energy.

TRAINING, SAFETY, AND MAINTENANCE

Personnel responsible for operating or maintaining UVGI units must be trained to ensure they understand potential hazards, control measures (i.e., engineering controls, administrative controls, and PPE), proper operation of the systems (e.g., selecting and using appropriate settings for the level of disinfection required), and maintenance procedures (e.g., keeping bulbs free of dust and changing bulbs)[17]. Proper installation, training, and control measures are critical to prevent worker injuries, and regular maintenance of UVGI systems—including cleaning of lamps—is critical to their continued effectiveness. To ensure optimum disinfection performance, follow the vendor's recommendations on lamp maintenance, including periodic cleaning. Material degradation may be a concern with some UV systems. See the following APHC guidance for additional information on control measures for UVGI lamps:

- APHC Fact Sheet No. 24-016-0316, *Hazard Alert for Upper Room Ultraviolet Germicidal Lamps*.
  https://phc.amedd.army.mil/topics/campaigns/covid19/Pages/facilities.aspx

- APHC Fact Sheet No. 24-013-0316, *Hazard Alert for Ultraviolet Germicidal Lamps Used In Air Handling Units*.
  https://phc.amedd.army.mil/topics/campaigns/covid19/Pages/facilities.aspx

- APHC Technical Information Paper No. 24-103-0320, *Effectiveness and Safety Of Ultraviolet Germicidal Irradiation Lamps Used for Air and Surface Disinfection*. https://phc.amedd.army.mil/topics/campaigns/covid19/Pages/facilities.aspx

HEALTH CONCERNS

Some UVGI lamps generate ozone, which may pose a workplace hazard if the room is not adequately ventilated. Verify that the UV unit does not generate ozone or is compliant with National Institute of Occupational Safety and Health (NIOSH) recommended exposure limits.

UVGI lamps emit UV radiation that poses a significant hazard to the cornea and skin. UV-related injuries to the eyes (photokeratitis) and skin (erythema or "sunburn") may occur. Proper installation, training and control measures are critical to their safe use. Appropriate precautions should be taken and necessary PPE worn when using such units. See the APHC guidance above for additional information on health hazards.

APHC supports the use of UVGI only if all the following measures are taken to maximize the effective use of the systems:

- System use is conducted by personnel trained on proper usage, potential hazards, and control measures.
- Systems are used in areas where this type of treatment is practical.
- Surface disinfection units are used in conjunction with pre-cleaning to maximize effectiveness.

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