COVID19 Disinfection – Ultraviolet Germicidal Irradiance

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1.0 Abstract:

Disinfecting SARS-COV-2 through various viable chemical germicidal methods are rapidly establishing throughout the world. Inherent toxic chemical properties of such germicidal products invariably seek other adjunct methods for disinfection. Ultra Violet Germicidal Irradiance (UVGI) has been a promising adjunct method on disinfecting microbial environment. This article considers the effectiveness of UVGI on infectious contaminated air and material surfaces (not on human dermal or ocular surfaces). UVGI treatment on water has not be considered in this article.

2.0 Background:

Airborne transmission of viral, bacterial infectious agent caused by sneezing, coughing are prone to get dispersed in air depending on the particle size of the droplet. The droplet nuclei can remain longer in the air stream compared to larger droplet particle size of more than 5 µm dia. Various factors such as force of expulsion, air velocity, humidity, infectivity determine the airborne transmission. It is estimated that lipid-enveloped virus such as human coronavirus survive in an environment lesser than 50% RH leading to a conclusion of maintain higher RH (>80%) and eradicating such viral load becomes trickier with normal chemical germicidal methods.

3.0 Ultraviolet Germicidal Irradiance (UVGI):

Ultraviolet Germicidal Irradiance (UVGI) principle use Ultraviolet short wave length UV(C) energy to inactivate the infectious virus and or bacterial load. The Ultraviolet spectrum is in the range of 100 to 400 nm. The spectrum can be split as UV (A) of 315 to 400 nm, UV (B) of 280 nm to 315 nm and UV (C) of 200 nm to 280 nm. The effective wave length for inactivation of microorganism considered to be at 265 nm on which 253.7 nm (UV (C) wave length) shows more effective in SARS viruses. UV dose (mJ/ cm^2) is functionally dependent on exposure time duration and the average irradiance (µW/cm^2). While deciding the required dose for inactivation, it is important to consider the species dependent inactivation constant (k). The survival fraction rate (s) of the microbial inactivation of UV(C) exposure is exponential to the dose. Single pass inactivation rate is the indicator of overall UVGI effectiveness. The effectiveness of the inactivation is extremely species dependent. Spores which are larger particles have least effect on UVGI and can be filtered out easily. Hence, combination of highly efficient filters and UV (C) have shown higher efficacy in many studies.

A study on inactivation of viruses using UVGI concludes that 90% viral reduction was obtained by UV(C) dose of 1.32 to 3.20 mJ/cm^2 for ssRNA, 2.50 to 4.4.7 mJ/cm^2 for ssDNA, 3.80 to 5.36 mJ/cm^2 for dsRNA, and 7.70 to 8.13 mJ/cm2 for dsDNA. For obtaining 99% viral reduction, double the dose of 90% viral reduction was required. Virus on surface with single stranded nucleic acid were more susceptible to UV inactivation than virus with double stranded nucleic acid.

Four different types of UVGI devices / treatment systems are as follows:

3.1 Upper-Air UV(C) Devices:

These devices are used to inactive the airborne infectious pathogens within the indoor environment. Transmission of infectious pathogen inside building happens through 'within-room' exposure and 'beyond room' exposures through corridors and entrainment in ventilation duct which is recirculated throughout the building. Natural or mechanical ventilation with good air mix inside the contaminated room ensures infectious pathogens encounter with the UV (C) and gets inactivated.

CDC has published a guideline based on a study conducted to control Mycobacterium Tuberculosis by Upper-Room Ultra Violet Germicidal Irradiance. In this study, parameters such as UV fluence rate required to inactivate Mycobacterium Tuberculosis surrogates, measuring fluence rate, UVGI performance through air mixing, relationship between UVGI system & mechanical ventilation, effect of humidity and photo-reactivation, placement of UV fixtures were studied. The study concluded that a well-designed UVGI system may kill or inactivate airborne Tuberculosis bacteria and protect the health care workers.

US Centre of Disease Control and Prevention in its Environmental Infection Control in Health Care Facilities suggest to install UVGI units in exhausts air ducts of HVAC system to supplement HEPA filtration or install UVGI fixtures on or near ceiling to irradiate upper room air.

Upper Air UV(C) fixtures is best suited for an occupied space with less than 10 feet ceiling height, such fixtures can be fitted at an elevation of 7 feet from the floor level considering well air mix. Ceiling height above 10 feet may allow for more open fixtures leading to larger irradiation zone. On the perspective of human safe guard, UV radiation of 0.4 $\mu W/cm^2$ at eye level is an acceptable engineering guide.

3.2 In-Duct UV(C) Devices:

In-Duct UV(C) system distributes UV energy in a specific area of the air duct of an Air Handling Unit (AHU) to deliver an appropriate dose to the air moving through the irradiated zone. Bacterial inactivation studies using BCG mycobacteria and Serratia Marcescens (Nosocomial related) have estimated the effect of UVGI as equivalent to 10 ACH to 39 ACH. Another study, however, suggests that UVGI may result in fewer equivalent ACH in the patient-care zone, especially if the mixing of air between zones is insufficient. The use of fans or HVAC systems to generate air movement may increase the effectiveness of UVGI if airborne microorganisms are exposed to the light energy for a sufficient length of time. Design of In-Duct UV(C) irradiance should consider single-pass inactivation under worst condition of air temperature and air velocity in the irradiated zone. At an average duct velocity of 500 ft / min, an irradiance zone of 8 feet can achieve 1s exposure. As a rule of thumb, a minimum of 0.25 s of UV exposure shall be established to minimize cost and power consumption. The required average irradiance may vary from 1000 $\mu W/cm^2$ to 10000 $\mu W/cm^2$ depending upon the k factor of the pathogen to be eradicated.

3.3 Room Surface Treatment:

Room Surface Treatment using UV(C) is more preferred in health care facilities to reduce number of microorganism on surfaces. UV(C) can also be applied in commercial establishments where surfaces can be irradiated using UV(C) fixtures along with other disinfection methodologies.

A study conducted from University of Auckland estimates that a minimum dose for UV(C) for deactivation of SARS-COV-2 on N95 filtering face piece would likely be close to 1000 mJ/cm^2

A working group from Cleveland Clinic Lerner Research Institute and Case Western Reserve School of Medicine published research paper on UV sterilization of N95 respirator placed within a Bio Safety Cabinet with manufacturer's reported fluence of 100 $\mu W/cm^2$ for reuse after approximately 15-20 minutes per side. The amount of dose shall be dependent on surface on which it is applied and the desired disinfection level. UV(C) irradiates at all line of sight objects and into shadowed areas depending upon the absorbent and reflecting property of the surfaces. The base on deciding the irradiant dose shall be dependent on the length of exposure, Intensity of source and distance from the source to surface.

3.4 Coil and Drain Pan Treatment:

Coil and Drain Pan Treatment if untreated can promote growth of biofilms containing mold and bacterial growth on damp or wet surfaces such as cooling coil, drain pans, humidifiers, filters etc., Conventional method of treating such bio growth organism is through mechanical cleaning and using chemical disinfectant. UV(C) has shown effectiveness in minimizing growth of such microorganism. Unlike air disinfection irradiance levels which exceed 1000 $\mu W/cm^2$, coil surface irradiance level would best achieved in the range of 50 $\mu W/cm^2$ to 100 $\mu W/cm^2$.

UV(C) is low penetrating on to human tissues compared to UV(A) or UV(B). Ocular damage to UV(C) can cause

Photokeratititis and Photokeratoconjunctivitis with similar symptoms of conjunctivitis. These symptoms resolve within a day or two, however chronic exposures can lead to development of cataracts. Cutaneous damage predominantly happens with erythema at a wavelength of 296.7 nm in the UV(B) band. UV(C) radiation particularly at 253.7 nm is less effective in causing erythema. UV(C) energy does not penetrate through solid objects and is attenuated through most of the solid objects. Chronic exposure to UV(C) can lead to skin ageing process and increase risk of skin cancer. UV(C) is classified as a probable human carcinogen by National Toxicology Program (NTP).

ACGIH TLV & Biological Exposure Indices limits the daily exposure based on Effective Irradiance to 0.003 J/cm^2. TLV for 0.500 Relative Spectral Effectiveness at 254 nm is 6.0 mJ/cm^2. Exposure duration for actinic UV radiation effectiveness (mW/cm^2) for 8 hours is 0.0001, 4 hours is 0.0002, 2 hours is 0.0004, 1 hour is 0.0008, 30 minutes is 0.0017 and for 1 minute is 0.05.

4.0 Summary:

UVGI depends on the exposure level of the infectious pathogens. Substantial evidence is still required to validate Upper-Room UVGI, In-Duct UVGI or Surface Treatment to protect occupants from infectious viral spread such as SARS-COV-2. Considering proven TB disinfection levels, UVGI technology is promising but requires a validated test protocol pertaining to SARS-COV-2. UVGI can be considered as a supplement to existing disinfection methodologies but not as a stand-alone disinfection treatment.

5.0 Reference:

a) CDC - Guidelines for Environmental Infection Control in Health-Care Facilities

b) Application of Ultraviolet germicidal irradiance disinfection in health care facilities – Association of professional in Infection Control and Epidemiology

c) Inactivation of viruses on surfaces by Ultra Violet Germicidal Irradiation – Journal of Occupational and Environmental Hygiene

d) Rapid evidence summary on SARS-COV-2 survivorship and disinfection, and a reusable PPE protocol using double hit process – University of Auckland

e) UV Sterilization of Personal Protective Equipment with Idle Laboratory Biosafety Cabinets During the COVID-19 Pandemic - Cleveland Clinic Lerner Research Institute and Case Western Reserve University School of Medicine, Cleveland, OH, USA