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ISHRAE POSITION PAPER ON THE USE OF TECHNOLOGIES ASSOCIATED WITH ULTRAVIOLET GERMICIDAL IRRADIATION FOR AIRBORNE INFECTION CONTROL WITH PARTICULAR EMPHASIS ON SARS CoV2 VIRUS.

AUGUST 2021

FOREWORD:

ISHRAE, as a part of its objective to disseminate knowledge, has taken initiatives to publish Guide books, standards, Data books and position papers to address various HVAC&R requirements specifically in the Indian context. This position paper is one of the many initiatives undertaken in the same direction to impart learning & knowledge in this all important field of UVGI.

ISHRAE has a very active Technical committee well supported by nearly 30 technical groups addressing all possible aspects of the HVAC&R industry. We seek interested and knowledgeable professionals to come forward and volunteer to serve the society and industry and thus lead to technical excellence.

The document is an outcome of the dedication and passion of the UVGI technical group members and we thank each one of them.

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ISHRAE Technical Committee Chair

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PREFACE:

Effectiveness of Ultra Violet Germicidal Irradiation (UVGI) in combating contagious virus and bacteria in occupied spaces has been recognized by the scientific community for many decades now. Evidence is available of UVGI systems being successfully deployed during the mid-20th century to mitigate the then prevailing pandemics such as Tuberculosis.

Use of UVGI is not new to India and has been in use in Healthcare facilities, Airports and Metro stations amongst other applications during the last two decades. The recent spread of Covid 19 across the world in wave after wave has brought the spotlight back onto UVGI , and deservingly so.

ISHRAE has published a "COVID19 Guidance Document for Air Conditioning and Ventilation" in April 2020, providing information on preparing the workplace to re-open after the lockdown. The key take-away to contain infection spread through air stream, in occupied spaces using HVAC system, is to enhance air filtration and to deploy UVGI in the HVAC system.

This position paper on UVGI, addresses the questions and myths surrounding the UVGI - from different stakeholders and provides relevant technical information and in the right perspective.

ISHRAE TECHNICAL GROUP ON UVGI

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1. INTRODUCTION:

It is now an acknowledged fact that airborne transmission is a major factor in the spread of Covid 19 infection, especially within enclosed spaces. The SARS CoV2 virus which causes Covid 19, transmits and proliferates not only through close contact and surface contamination but also through inhalation of the very fine particle mist exhaled by an infected person which remains suspended in the air for long periods[1]

In view of the extremely small size of the virus, conventional filtration technologies are largely ineffective. Also, filtration systems capable of isolating the virus from the airstream are not practical because of cost and space considerations.

It is in this context that Ultraviolet Germicidal Irradiation (UVGI) has emerged as a possible solution to eliminate the virus in recirculating air systems.

The purpose of this document is to detail certain UVGI Technologies which are currently available and are purported to be useful to deactivate bacteria and viruses in general and the SARS- CoV2 virus in particular in air conditioned and /or ventilated indoor spaces.

While there are other technologies such as bi-polar ionization which are being tried out for the same purpose, this paper confines to UV based systems.

2. The SARS- CoV-2 VIRUS AND ITS TRANSMISSION IN HUMAN BEINGS:

This virus is made up of RNA encapsulated in a protein shield and has protein spikes which latches on to the host cell and then starts multiplying. Since its inception, this virus has undergone several mutations[a] increasing its spread across continents. It now appears that in its several mutated[a] forms, this virus will be with us for a long time.

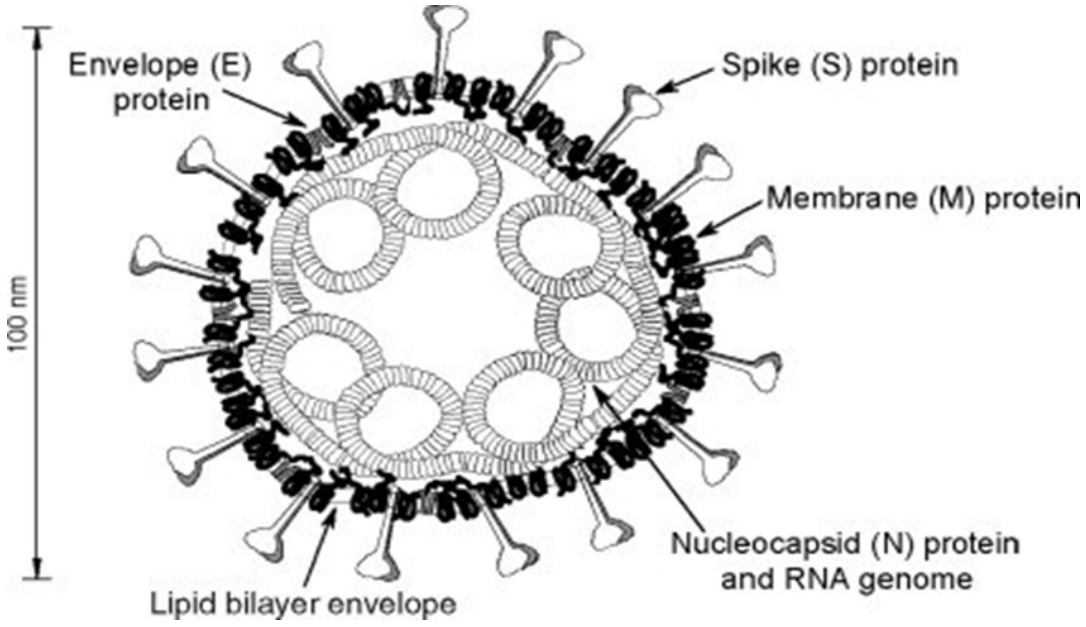

FIG 1. Schematic of the coronavirus[2]

We also need to understand what the size of the virus is. Corona virus is of the order of 0.08 to 0.12 µm (micrometer). Image below compares the size of virus with respect to certain other particles.

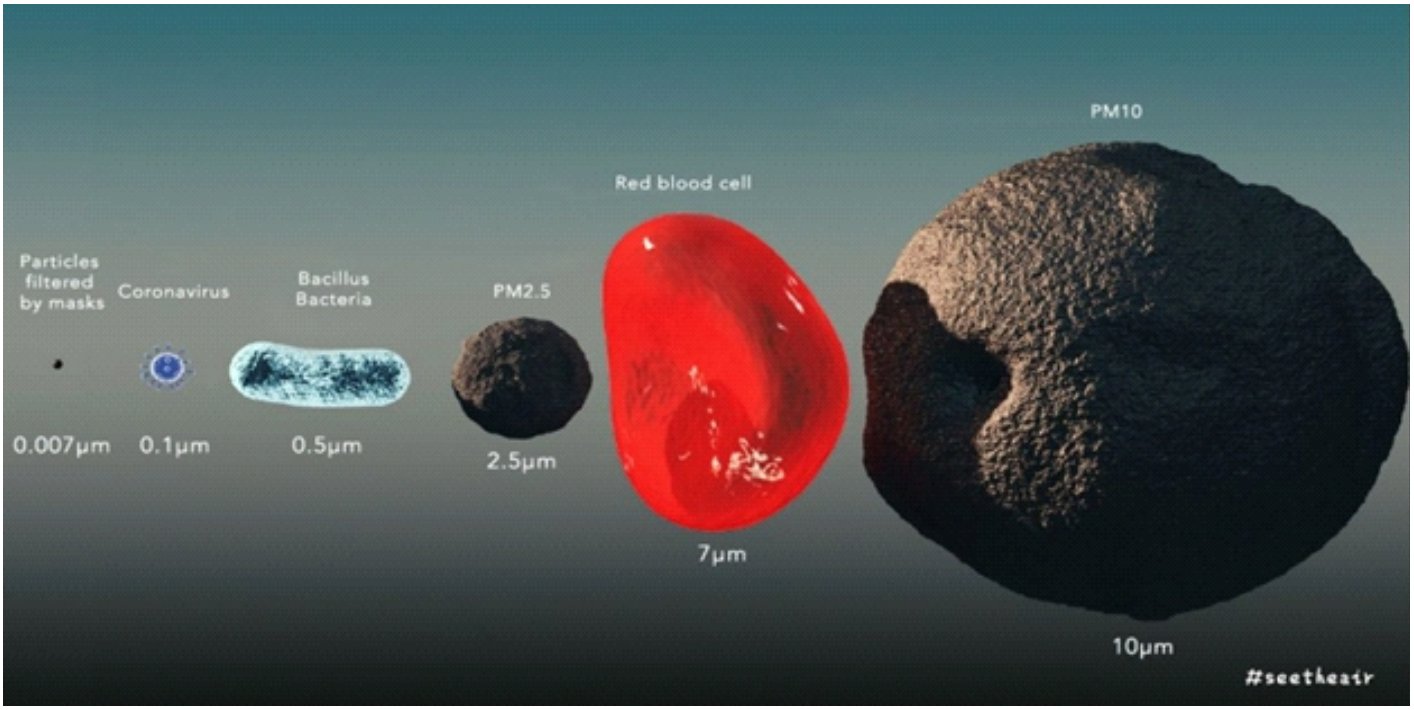

FIG 2. Size of Coronavirus [3] [b]

- The SARS CoV2 virus is seen to spread from person-to-person mainly through respiratory droplets as well as through exhalation/inhalation.[4][5]
- Infectious respiratory droplets are produced when an infected person coughs or sneezes. [4][5]
- Droplets can land near the mouths or noses of nearby people. [4][5]
- Droplets can land on surfaces and can spread through contact with contaminated surfaces. [4][5]
- When in close contact with an infected person, droplets can be inhaled into the lungs. [4][5]
- Virus can be present in the exhalation of an infected person and can remain suspended in the space for considerable length of time (depending on temperature and humidity conditions in the space)[4][5]
- Virus thus remaining suspended can be transmitted through airflow streams both with in the space as well as by recirculation through a conditioning unit.[4][5]
- Studies have shown that toilets can also be at risk of generating airborne droplets and droplet residues that could contribute to transmission of pathogens. [4][C]

3. INDOOR AIR TREATMENT WITH ULTRAVIOLET GERMICIDAL IRRADIATION:

Ultraviolet germicidal irradiation (UVGI) is capable of inactivating various bacteria, virus, fungi, and spores so that they are unable to replicate the cells. [6]

The entire UV spectrum is capable of inactivating microorganisms, but UV-C (wavelengths of 200 - 280 nm) provides the greatest germicidal effect, with 265 nm being the optimum wavelength. [6]

The majority of modern UVGI lamps create UV-C energy with an electrical discharge through a low-pressure gas (such as mercury vapor) enclosed in a quartz tube or a tube made of UV transmitting soft glass , similar to fluorescent lamps. [6]

Roughly 95% of the energy produced by these lamps is radiated at a near-optimal wavelength of 253.7 nm. [6]

UV-C light-emitting diodes (LEDs) are also emerging for use. However, this is still under research/development. [7]

The various technologies available for Indoor air quality treatment with UV-C related technologies are described herein below: [6]

- UV-C in Air Handling Units. These were primarily developed for cooling coil and drain pan disinfection[d] and are currently being extended to airstream disinfection, to the extent possible.
- UV-C In duct airstream disinfection[d]
- UV- C for Upper region room irradiation.
- UV-C Portable Room Units
- Photo Catalytic Oxidation
- Advanced oxidation process.

Each of the above technologies have specific design considerations, installation requirements and safe practices which are briefly detailed below.

3.1 AHU COIL UV-C TREATMENT:

The cooling coil within the Air Handling Unit (AHU) dehumidifies the water vapor contained in the air and the condensed vapor makes the coil moist. The dirt and debris in the air combines with this moisture on coil and enables microbes present in the air to feed on the dirt and create a biofilm on the coil. The buildup of bio film[e] on the coil retards heat transfer and offers more resistance to air flow. [6]

UV-C light of 254nm wavelength have the capability to break the RNA/DNA of microbes, thereby retarding their survival and multiplication. [6]

This disinfects and cleans the coil surface as well as the drain pan. Resulting reduction in resistance to airflow improves the energy efficiency. A clean coil and drain pan improves the indoor air quality also. [6]

Apart from coil cleaning, for which UV-C was traditionally used, the air stream can also get disinfected based on the dosage[f] imparted by the UV lamp. UV-C Intensity[g] required for air stream disinfection is higher than that required for disinfecting the coil and drain pan. This is on account of the low exposure time the pathogens[c] in the air stream get as against the coil being exposed all the time.

Each microbe requires a specific dosage[f] for disinfecting to a certain degree - referred as log scale of reduction. For example, for the SARS-CoV2 virus a 99.9% (3-log) reduction requires a dosage[f] of 37 J/m^2 (3,700 µw-sec/cm^2)[8] With an air velocity of 2.5 m/sec across the coil and the minimum exposure time of 0.25 to 0.4 seconds recommended for effectively disinfecting the moving air (as recommended by ASHRAE), the length of the irradiation zone with in the AHU will range from 600 to 900 mm with a UVGI system irradiation intensity[g] of 9,250 µw/cm^2.

Note : This is presented as an example and design calculations are recommended in each case depending on the disinfection desired ,the type of bacteria or virus which is sought to be eliminated and the radiation intensity and length of irradiation zone possible with the specific AHU design.

While lamps with reflectors were originally used for coil disinfection, airstream disinfection efficacy is improved with 360 degrees irradiation UV-C lamps without reflectors. Absence of a reflector does not have any impact on coil cleaning efficacy (on account of the lamp intensity being high)

3.1 .1 INSTALLATION/ MAINTENANCE:

It is recommended to install UV-C lamp downstream[h] of the cooling coil, since it gives access to irradiation[g] of the drain pan and keeps AHU plenum devoid of mould growth, as more condensation happens downstream. As mentioned above, the UV lamps can be installed either with reflectors (if coil and drain pan disinfection is only desired) or without reflectors (if air stream disinfection is also desired). In case air stream disinfection is required, the radiation intensity[g] and the exposure time needs to be worked out between AHU supplier and UV-C vendor. [6]

Surface disinfection must be operated on a 24 x 7 basis to prevent microbial growth. However, lower radiation intensity will suffice. [6]

Where high intensity UV-C lamps for air stream disinfection are installed in the AHU, care should be taken to ensure that vulnerable materials such as filters, seals, gaskets etc. are shielded or substituted. Otherwise, substantial degradation may occur resulting in decreased filtration efficiency, defective seals, and damaged system components, causing possible loss in system performance and/or potential safety concerns. [8]

It is recommended that the ballast[i] and assembly should be tested and certified by a reputed agency to the satisfaction of the customer.

For optimum performance the surface of UV lamps shall be cleaned with a wick wetted with spirit, at regular intervals. Frequency shall be suitably determined by observing dust formation frequency on lamp surface.

It is important to replace the lamps strictly as per manufacturer's recommendation .This is stressed on account of the possible reduction in intensity of irradiation over a period of time even though the lamps continue to be functional.

Touching the lamp with fingers shall be avoided, as the fingerprints or stains on the lamp surface might interfere with its effective function.

3.2 UV-C IN-DUCT AIR DISINFECTION:

The principal design objective for an in-duct UV-C air disinfection system is to deliver the appropriate UV dosage[f] to the air moving through the irradiated zone with minimum system power.

Exposure time is a function of air velocity within the duct and the length of the irradiation zone. ASHRAE recommends a minimum exposure time of 0.25 to 0.4sec, for effectively disinfecting a moving air stream.

As detailed in Section 3.1 in respect of air stream disinfection within the AHU, the disinfection can be attempted inside the supply air duct. For the identical values of UV-C dosage and exposure time as given in the example (Section 3.1 above) air velocity of 7.5 m with in the supply air duct will require irradiation zone of 3 m length.

Designer has to consider the dosage[f] required for disinfecting the specific microbial substance to estimate the irradiation intensity[g] of the UVGI system. Based on the dosage[f] and the available exposure time, one needs to select the specific intensity, type and number of lamps required. Exposure time and the air velocity in the duct will determine the length of the irradiation zone within the duct. Depending on the supply air ducting layout and site constraints, designer can decide to apply the UVGI either in a plenum or in the main duct -preferably before branching out - to minimize the first cost and subsequent replacement issues.

To repeat, the UV-C dosage[f] required, the air stream velocity and the exposure time are the key parameters, while designing required intensity of UV-C lamps. Any increase or decrease in air velocity will require proportionate increase or decrease in the length of irradiance zone.

3.2 .1 INSTALLATION/ MAINTENANCE:

UVGI may be installed in either supply or return air ducts for normal air conditioning applications and in exhaust air ducts from patient area in hospitals or for toilet exhaust ducts.

For UVGI, a fairly uniform velocity distribution across the duct is desirable because it generally provides uniform particle loading, and irradiating all of the microorganism particles is the goal. That means UVGI has to be installed in a symmetrical fashion. While the installation can be either perpendicular to the direction of airflow (cross flow) or parallel to the direction of airflow, crossflow installation has been found to be more efficient in deactivating bacteria and viruses.[10]

It can be installed either in a horizontal or vertical direction.

Unique lamp holders are recommended, which will prevent the usage of non- standard UVC lamps as replacement at a later date.

UVC lamp can be in a sleeve to prevent glass breakage and mercury spillage.

Cleaning of lamps and replacement of lamps should be as detailed in Section 3.1.1.

All Electrical parts and accessories shall be UL listed or equivalent certified.

The ducted UVGI system can be interlocked with the AHU and can be integrated with BMS.

3.3 UVC UPPER AIR DISINFECTION:

Upper zone irradiation units are proven to be highly effective in Hospitals and such other applications, and UV-C lamps disinfect the air coming in its range either through normal convection currents or through mechanical air flows. The lamp holder will be equipped with a set of baffles which are designed to deflect practically all the radiation emitted by the lamps to the top portion of the room. The design of the unit and its installation will be such that leakage of UV radiation into the occupied zone should be validated with in ACGIH [k] limits (0.1µw/cm^2 for broadband UV or 0.2µw/cm^2 for UV-C at a wavelength of 254 nm). This will determine how much of UV lights can be safely installed within the space.

3.3 .1 INSTALLATION/ MAINTENANCE:

The fixtures mounted in occupied spaces should be at a minimum height of 2.15m from floor level.

- Requires low UV-reflectivity of walls and ceilings
- Ventilation should maximize air mixing.
- Use supplemental fans where air movement is insufficient.

Cleaning of lamps and replacement of lamps should be as detailed in Section 3.1.1.

3.4 UV-C PORTABLE AIR DISINFECTION UNITS:

Where there are no central air conditioners and stand -alone systems like split units, VRF units are used, air purifiers with UV-C may be used to disinfect indoor air.

There are four main types of portable Air Disinfection units, which use UV-C:

3.4 (A) Modular Mobile HEPA-UV-C unit:

These units use an H-13 or H-14 grade HEPA filter and a UVGI lamp of adequate intensity. These are used in hospitals for converting a general ward into an Isolation room operating under negative pressure. The air is vented out through filters and UVGI so that neighborhood is not polluted.

The units can also be used for re-circulation of the air within the room, thus controlling the dust level as well as microbial presence in the circulating air.

3.4 (B) Residential or Commercial Air purifiers:

These mobile units use high grade pleated filters with MERV ratings of 14 or higher for dust control, activated carbon filters for VOC control and UV-C lamp of adequate intensity for microbial control. Some of the units use Photo catalytic oxidizer along with UVC for deactivating the pathogens. The models are suitably selected to achieve a specific Clean Air Delivery Rate (CADR)[j] value for a given size of room.

3.4 (C) Hand-held surface disinfection units:

These are compact, hand-held units with a high output UVGI lamp. Lamp is sleeved to prevent glass breakage and spillage of mercury. These can be used for disinfecting beds in hotels and hospitals as well as any other surfaces liable to be infected. These are also found useful for Air Craft Cabin disinfection. Training is required for using these units to avoid exposure of eye, fingers, forehand or face to UVGI rays.

3.4 (D) Portable room disinfection units:

These are operated remotely, leaving the unit inside the room to be disinfected. Typical examples are Operation Theatres which require high dose of UVGI energy to deactivate pathogens. Manufacturer's recommendation should be followed on the number of hours of operation within the room, which will depend on UVGI Intensity, volume of the room and the type of pathogens, which determines the dose.

3.4 .1 INSTALLATION/ MAINTENANCE

These are mobile plug & play type of units and do not require any special installation instructions. Clean room Delivery rate (CADR)[j] required is to be confirmed with manufacturer. Number of air changes per hour (ACH) will need to be considered by the user in line with applicable standard/code. Device is placed near the area where disinfection is desired. Air distribution and spacing has to be checked.

Multiple units will offer better coverage. Acoustic considerations needs to be checked.

Units are equipped with alarm indicators for filter replacement. Similarly, UVC lamps have to be replaced after the stipulated running hours.[11]

Lamps used in hand-held surface disinfection units are recommended to be used with a sleeve or a protective cover to avoid spillage of broken glass pieces or the mercury dose within the lamp.

3.5 OTHER EMERGING TECHNOLOGIES:

There are several technologies which use UV Radiation directly or indirectly for disinfection of pathogens in an air stream or within a space. Examples are Photo Catalytic Oxidation (PCO) and Photo Hydroxyl Ionization (PHI). Such processes use UV light of different intensities and the wavelength of the UV is selected depending on the nature of the catalyst used in the process .Objective is to produce Hydroxyl Radicals and/or Super Oxides (Reactive Oxygen species) which react with contaminants such as Bio Aerosols and VOCs. Adopting such technologies for microbial content in the air stream is an emerging trend.

The efficacy as well as safety of such technologies are under research and are yet to be fully established .Users are advised to evaluate all test data provided by manufacturers before adopting these technologies for disinfection purposes.

For more information on such air cleaning technologies please refer to ISHRAE Publication "Air Purifier Guide Book "

3.6 UV-C AND SAFETY:

UVC light is not visible and the bluish tinge is because of small visible light bands that it produces. If exposed to human body, UV-C light is harmful to the cornea and it affects the superficial levels of the skin. It doesn't penetrate to the epidermis or the living cells.

UVC light with wavelengths less than 200nm have the potential to produce ozone. This could be harmful and needs to be avoided .On-site validation must be done prior to procurement of the same.

All UV-C low pressure 254 nm lamps contain a tiny amount of mercury .Utmost care is advised when the lamps are replaced to follow a safe disposal method similar to the disposal of fluorescent lamps containing mercury.

It is necessary to avoid any contact or exposure to UV-C light. This is applicable for all UVGI related technologies.

All other safety requirements for Electrically operated devices as per applicable Standards and Codes are to be observed.

4. TERMINOLOGY:

(a) Mutation /Mutate: The more a virus spreads and causes infection widely, it also gets opportunities to change its own genetic structure. This different form is called mutant. It could affect the virus' property such as transmission or severity in a positive or negative manner.

(b) PM2.5, PM10: Particulate Matter i.e. dust level size of 2.5 µm, 10 µm etc.

(c) Pathogen: Microorganisms like bacteria and virus which cause disease.

(d) Disinfection: A process of inactivating microorganisms. This process is milder than Sterilization.

(e) Bio-film: Group of microorganisms sticking to a surface and keep replicating multifold.

(f) Dosage (of UV-C): This is the product of the UV-C irradiance and the exposure time. (UV-C Dose = UV-C Irradiance x Exposure time). Unit of UV-C Dosage is milli Jules/cm^2 or Joules/m^2. Each pathogen require a specific UV-C dosage, to get disinfected to a certain degree, referred as logarithmic scale of reduction.

(g) UV-C Intensity or Irradiance: This is the power of electromagnetic radiation incident on a surface per unit area. Expressed as microwatt/cm^2 (µw/cm^2)

(h) Downstream (of AHU coil): Space available within the AHU, after air has passed through the cooling coil. (i.e. the space between coil and blower).

(i) Ballast: An electronic or electromagnetic device, appropriately designed by the UV-C lamp manufacturer to match the lamp's electrical characteristics.

(j) CADR: The term generally used with mobile, self-contained Air Cleaners and Air Purifiers, to indicate the particle removal effectiveness.

CADR ≃ Air flow rate x Filtration efficiency.

(k) ACGIH: American Conference of Governmental Industrial Hygienists, a charitable scientific organization that advances Occupational and Environmental Health.

5. REFERENCES:

(1) US- CDC Advisory on spread of Covid 19 Infection - May 2021

(2) The Molecular Biology of Coronaviruses - Paul S Masters - Wadsworth Center, New York State Department of Health Albany, New York 12201

https://europepmc.org/backend/ptpmcrender.fcgi?accid=PMC7112330&blobtype=pdf

(3) Size of Coronavirus particle, PM2.5 & Bacteria [Online],10th April 2020, Size-of-coronavirus-particle-pm2.5-and-bacteria-750x410.jpg (750×410) (smartairfilters.com)

(4) WHO Scientific Brief on transmission of SARS Cov -2 dated 09.07.2020

(5) Lancet Publication on Covid-19 transmission - Online, October 29, 2020

(6) ASHRAE HVAC Applications Handbook 2019

(7) International Ultraviolet Association White paper on Far UV-C radiation.

(8) ASHRAE HVAC Systems & Equipment Handbook 2020

(9) "UV irradiation is highly effective in inactivating and inhibiting SARS CoV 2 replication" - Research paper by Andrea Bianco ET.al published May 2020

(10) Defining the effectiveness of UV lamps installed in circulating air ductwork. - Douglas Van Osdell and Karin Foarde - Nov.2002

(11) ASHRAE document on In Room Air Cleaner Guidance for Reducing Covid 19

6. DISCLAIMER:

ISHRAE has compiled the information contained in this Position Paper with care. However, ISHRAE does not warrant that the information is free of errors. ISHRAE also does not endorse any of the technologies or products detailed in this publication and the use of any information contained herein above is entirely at the risk of the user. Careful evaluation of product and safety certifications is recommended and manufacturer's own recommendation on safety should be followed.

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7. ABOUT ISHRAE:

The Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE), was founded in 1981 at New Delhi by a group of eminent HVAC&R professionals. ISHRAE today has over 30,000 HVAC & R professionals and Student -members. ISHRAE operates from 44 Chapters and Sub-chapters spread across India with its Head Quarters in Delhi. ISHRAE is led by a team of elected officers, who are members of the Society, working on a voluntary basis, and collectively called the Board of Governors.

ISHRAE's Objectives:

- Advancement of the Arts and Sciences of Heating, Ventilation, Air Conditioning and Refrigeration Engineering and Related Services.
- Continuing education of Members and other interested persons in the said sciences through Lectures, Workshops, Product Presentations, Publications and Expositions.
- Rendition of career guidance and financial assistance to students of the said sciences.
- Encouragement of scientific research.

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