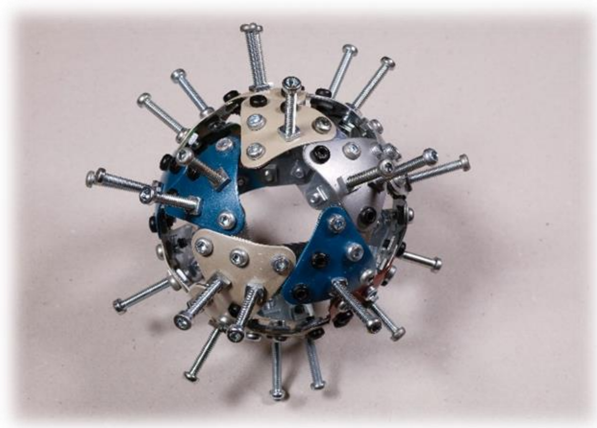
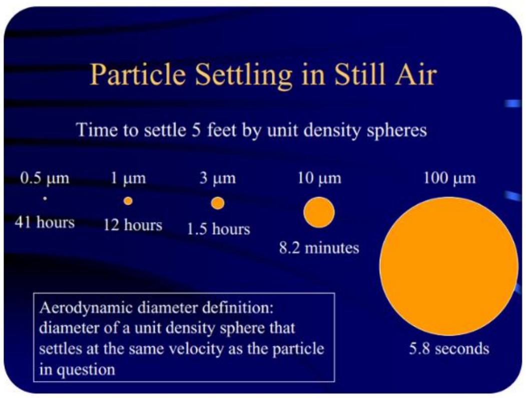
Application Notes: Ultraviolet Germicidal Irradiation (UVGI)



Covid-19 has arguably impacted everyone's lives in one form or another, causing governments, companies, and individuals to play a role in infectious disease control and prevention. To acknowledge the paradigm shift, the 20th century had brought about the digital age, as "we used to say every business will be a digital business. But, today [in the 21st century] we say every business will be a health business." This future trend projected by Accenture's Gianfranco Casati during an April interview with BBC is quite plausible. Even after this outbreak ends, the concern of the next pandemic will linger. How will future pandemics be confronted? How can we be better prepared?

Today's pandemic has presented multiple challenges that not a single solution, alone, can fix. The implementation of various solutions not only require ingenuity but also the involvement of each other's efforts. Sharing our knowledge and bolstering developments are few of the ways that QTB can contribute during these pressing times. Among many solutions, UltraViolet Germicidal Irradiation (UVGI) has gained recognition for air and surface disinfection of bacteria and viruses. This article aims to provide the background to UVGI and introduce the fundamentals to those evaluating options or just looking for a place to begin.

Before jumping into the UVGI topic, this subject needs a prologue to how bacteria and viruses can be transmitted. The larger droplets, that are expelled from human orifices make their ways through the air as well as onto the floor, continue to desiccate through the evaporation and absorption of water molecules. The particles shrinking in size give the bacteria and viruses the ability to go airborne and suspend in air for longer time periods. According to the CDC, the smaller particulates, the longer these particles remain in the air, as shown in the CDC illustrations below.



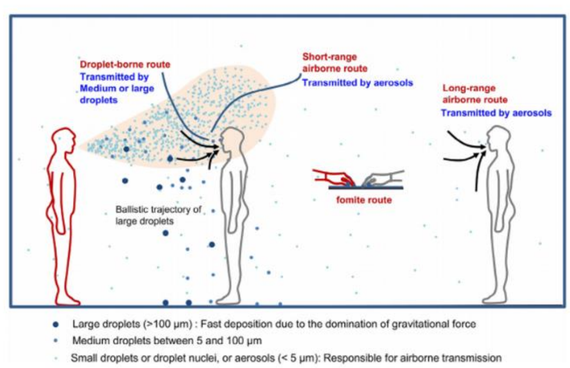


Fig 4. Illustration of different transmission routes. Small droplets (<5 µm), sometimes called aerosols, are responsible for the short-range airborne route, long-range airborne route, and indirect contact route; large droplets are responsible for the direct spray route and indirect contact route.

Such information has driven safety guidelines and precautionary measures for the general public to follow. However, as Personal Protective Equipment (PPE) also becomes the public's use and concern, the limitations of masks show that further development is needed in this field of protective measures and equipment.

While researchers were studying the effects of ultraviolet light on microorganisms and agents in the past century, the researchers made note of an interesting correlation that is captured in the following graph below. While there are a few exceptions, a pattern is recognizable between the size and type of genome. The RNA-based viruses tend to be smaller than the RNA- or DNA-based bacteria and fungi. In fact, coronaviruses such as Covid-19 and SARS are at the very limit of medical N95 masks' ability to filter. Other viruses such as Influenza A and B are a whole magnitude smaller than Covid-19, making these masks even less effective.

ASTM F2299:
PFE (Filtration 1µm)

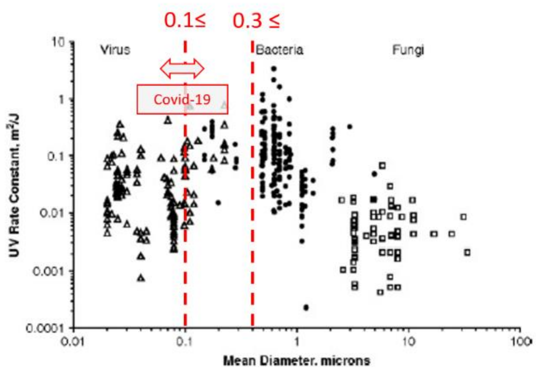


Figure 4.10 Plot of UV rate constants vs. mean diameter, in which no apparent general relationship between physical size and UV susceptibility can be discerned.

ASTM F2101:
BFE (Filtration 3µm)

In order to combat these viruses and smaller-sized bacteria such as Tuberculosis, many hospitals with front-line masking protocols, also employ closed and open air-purifying systems to further reduce bacterial and viral loads that potentially accumulate in occupied areas. Closed systems utilize positive pressure ventilation to provide clean air and exhaust the pre-existing. While closed systems do provide clean air, exhausted air takes time to evacuate and cannot easily compensate for sudden increase in occupants. Hospitals thereby add open air-purifying systems to supplement and effectively address this matter. One of the types of open-air systems that has been gaining popularity since New York City's success of containing Tuberculosis outbreaks, is known as the Upper Room UVGI system.

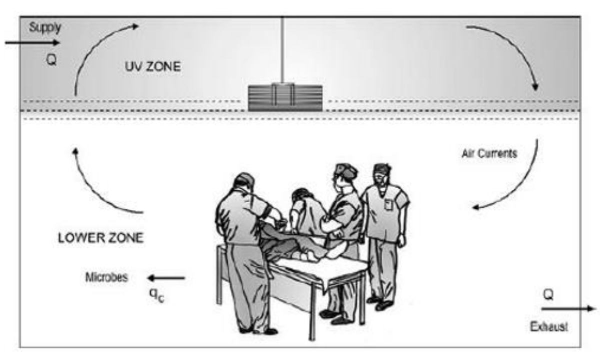


Fig. 9.7 Air will circulate into and out of the Upper Room UV zone while contaminants will be released continuously by occupants or other sources

UVGI, which stands for Ultraviolet Germicidal Irradiation, is <u>a disinfection method</u> that harnesses a particular range of the electromagnetic radiation spectrum (electromagnetic radiation often called light if visible to human eyes) **and exposes a target area with a germ-killing effect on viruses, bacteria, and fungi.** This particular range is widely accepted in the industry to be between 200nm and 280nm. In reference to other forms of electromagnetic radiation, 200nm and

280nm falls within a sub-category of Ultraviolet UV-C. This makes the terms of UVGI and UV-C interchangeable for germ killing discussions. Despite the term 'light' being reserved for the visible spectrum, 'non-visible light' is still colloquially used and understood.

For Upper Room UVGI systems, the UV-C light source covers a volume of air that naturally circulates from the rising of air warmed by the bodies below and sinking of cooled air from above. This air, once sanitized by the germ-killing effects of UV-C, provides "equivalent air changes." Such systems are often hung from the ceiling like a luminaire and point upwards toward the ceiling. The difference is louvers or shielding are required to reduce and limit exposure to humans below.

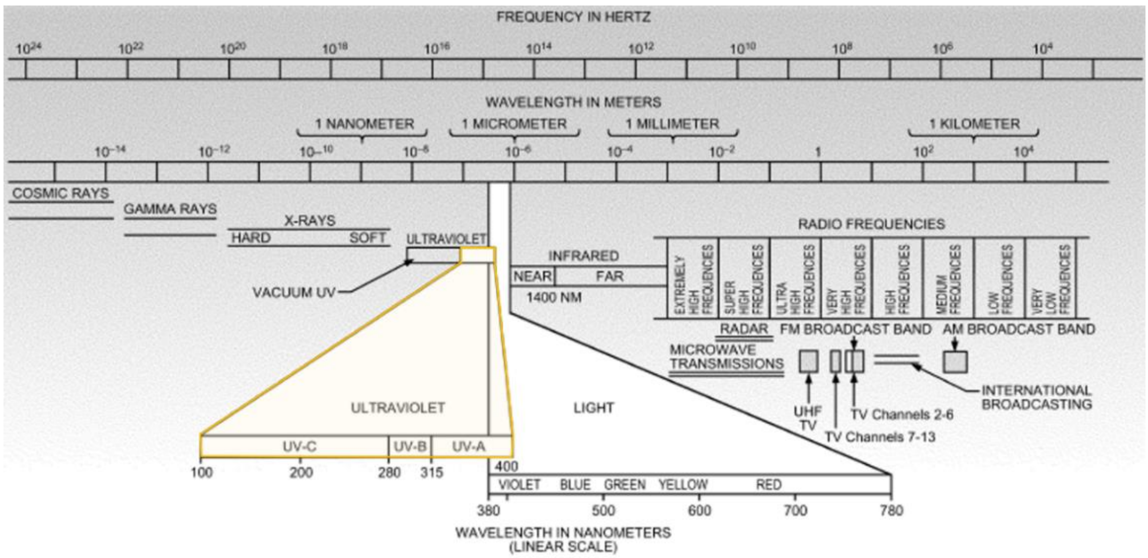
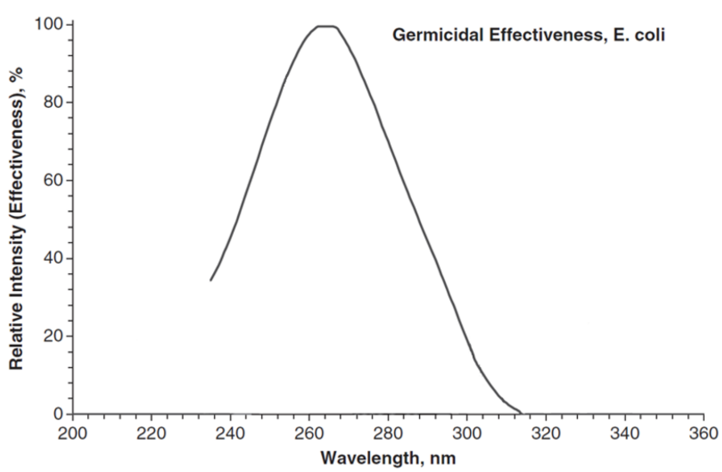


Fig. 2 Electromagnetic Spectrum
(IESNA 2000)

To emphasize, the wavelength is a property of electromagnetic radiation. In other words, this property, that is key for killing bacteria and fungi and inactivating viruses, is not to be mistaken for heat. Depending on the strain of microorganism or agent, certain wavelengths are more effective than others.

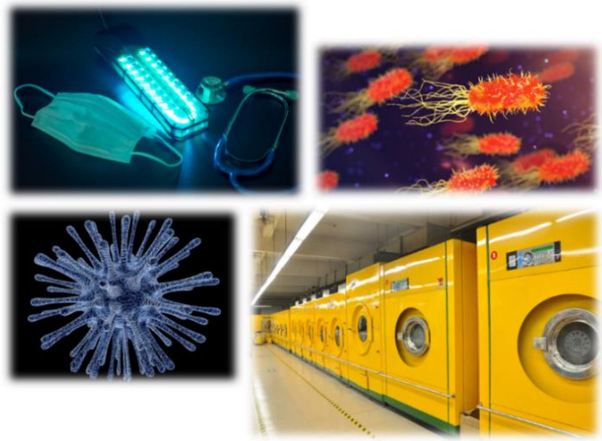


Germicidal effectiveness for E. coli. Based on data from Luckiesh (1946) and IESNA (2000)

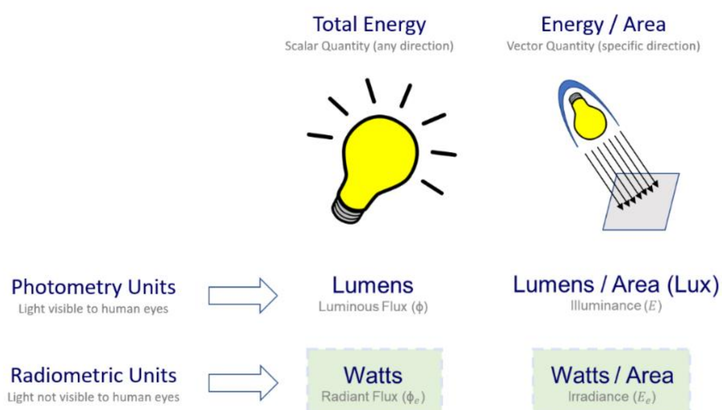
There are studies ongoing in the shorter wavelengths around 222nm. While this wavelength range has a lesser germicidal effect, 222nm may, potentially, be far less harmful to human skin and eyes, and therefore, theoretically safe for direct exposure. However, this development is still undergoing further research, along with other concerning health hazards such as o-zone production in these shorter wavelengths. For these reasons, QTB currently recognizes the UVGI application to pragmatically be within 240 to 280nm.

Band	Wavelength,nm	Type of Classification	
UVA	315-400	Non-germicidal (curing & blacklight)	
UVB	280-315	Erythemal (light therapy)	
UVC	240-280	Germicidal	Germicidal
	200-240	Ozone-producing	
	160-200		Vacuum UV
	100-200	Vacuum UV	

UVGI
Ultraviolet Germicidal Irradiation
240 to 280nm



Another key factor to UVGI is the amount of radiation/light that is absorbed by the intended object or surface. Due to the nature of light sources (traditional lamps and LEDs), only a certain amount of Ultraviolet UV-C light will be captured within the intended area. In many UVGI applications, these targeted areas are the focus and thereby require well-defined and measurable units. The units often used to describe Radiant Flux (Total Energy) and Irradiance (Energy/Area) are 'Watts' and 'Watts per Area.' Other units can be converted for equivalency.



The last dimension to take into account is the amount of time that such object or surface will be exposed. If the amount of energy per area is multiplied with time, we arrive at the total energy that has been absorbed by the object or surface, which is called 'dosage.' Dosage is what defines the amount of energy required to kill bacteria and inactivate viruses.

For the past several decades, researchers in this field have already published how much dosage is required to kill and inactivate 90% or more, for many strains of viruses, bacteria, and fungi. There lies the importance to understand these terminologies and units, in order to carry forward with studies of new and emerging infectious diseases.

In the previous example, we covered how UV-C light is used to disinfect air, but how about surfaces? Disinfecting surfaces may be more straightforward and effective to implement since the intended surface area is generally allotted to have longer exposure times. However, there is one drawback, the common theme observed in all surface disinfection applications is the lack of human presence. This is due to ultraviolet light being recognized as a safety hazard for human skin and eyes when overexposed. This is the limitation of surface disinfection.

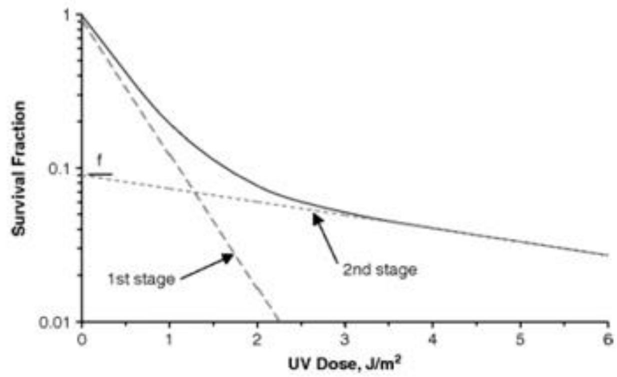


Fig. 3.2 A two stage decay curve is the summation of the first and second stages proportioned by the resistant fraction f






As a matter of fact, the earth's upper atmosphere filters out all UV-C and a good amount of UV-B, which provides us with very little understanding of what exposure to UV-C can naturally do. More concerningly, majority of humans are unable to see below 320nm; this is a problem since humans are, therefore, unable to rely on the aversion response to blink and look away. As UVGI is garnering more interest and usage in other industries, more lighting and health committees are further studying the effects and adding to their standards and guidelines of UV exposure limits. In the meantime, surface disinfection seems to remain limited to self-contained systems and rooms.

For those considering surface disinfection, many labs that certify safety of systems and products will use guidelines such as, but not limited to, IEC 62741, TR 62471-2, and ANSI/IESNA RP-27. Consulting with such experts or organizations is pertinent to successful product implementation.

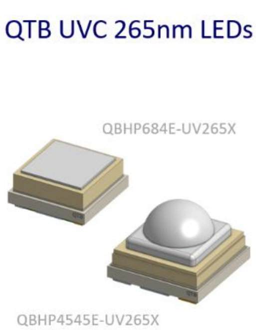
While UVGI is not the one-fix-all solution, this disinfecting method adds to the plethora of tools that when deployed in the right manner, can provide more control and prevention of infectious diseases. The Upper Room UVGI systems, biological safety cabinets, and static UVGI installations are only a few examples discussed, that have gain prominence in just the healthcare setting. These types of air and surface disinfection methods are only beginning to make headway in other sectors. With the public becoming more health conscious, more companies are starting to realize the broader applicability of UVGI in public settings and daily life. Each step along the way, we look to identify these applications, support the efforts, and take UVGI to the next level.

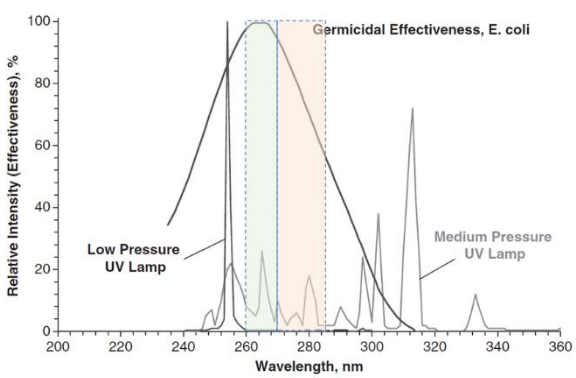




QTB foresees many companies and project teams finding innovative and refreshing ways to integrate UVGI into consumer interfaces and devices. Such interfaces and devices often have tightly confined spaces and more complex form factors. This is where UV-C LEDs thrives as a very capable solution. QTB is constantly expanding the UV-C LED portfolio to provide more performance, reliability, and tune-ability in order to effectively support these newer applications of Ultraviolet Germicidal Irradiation.

QTB offers a variety of standard low-power, mid-power, and high-power packages in two separate ranges of wavelengths: 260 to 270nm and 270 to 285nm.



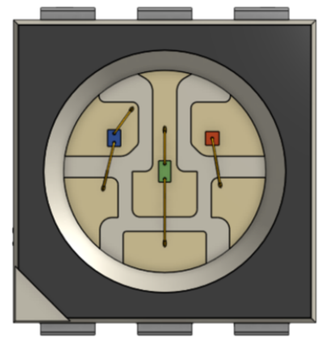


QT-Brightek Corporation
372 Turquoise Street, Milpitas, CA 95035 USA
Tel: 408-514-1522 ▪ Web: www.qt-brightek.com

The topic of UV-C and UVGI certainly has many more facets and depth that this article cannot cover in one piece. For further discussion, literature, and training, please contact our sales representatives that fall in the same region, or otherwise, contact us directly. Additional details and specifications about our latest UV-C LEDs for UVGI can be found at www.qt-brightek.com.

We hope you found this article informative, and as always, we thank you for your time!

Build For Quality,
Build Together.



References:

Baron, Paul. *"Generation and Behavior of Airborne Particles (Aerosols)."* CDC, NIOSH, 2010, https://www.cdc.gov/niosh/topics/aerosols/pdfs/Aerosol_101.pdf. Accessed 3 June 2020.

Harper, Justin. *"Accenture: 'Every Business Will Be a Health Business'."* BBC News, BBC, 15 Apr. 2020, www.bbc.com/news/business-52289142.

IESNA. 2000. *The IESNA lighting handbook*, 9th ed., Ch: 5: Nonvisual effects of optical radiation. M.S. Rea ed. Illuminating Engineering Society of North America, New York, NY.

Jianjian & Li, Yuguo. *"Airborne spread of infectious agents in the indoor environment." American Journal of Infection Control*, 2018, https://www.ajicjournal.org/article/S0196-6553(16)30531-4/pdf. Accessed 3 June 2020.

Wladyslaw Kowalski, *Ultraviolet Germicidal irradiation Handbook, UVGI for Air and Surface Disinfection*, DOI: 10.1007/978-3-642-01999-9, Springer-Verlag Berlin Heidelberg 2009

QT-Brightek Corporation
372 Turquoise Street, Milpitas, CA 95035 USA
Tel: 408-514-1522 ▪ Web: www.qt-brightek.com