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Sayantani Chakraborty
Department of Microbiology, Swami Vivekananda University, Barrackpore, West Bengal, India

Sibashish Baksi
Department of Biotechnology, Swami Vivekananda University, Barrackpore, West Bengal, India

Corresponding Author:
Sibashish Baksi
Department of Biotechnology, Swami Vivekananda University, Barrackpore, West Bengal, India

A thorough study of the efficiency of UV light-emitting technologies against coronaviruses

Sayantani Chakraborty and Sibashish Baksi

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Abstract
A worldwide pandemic crisis brought on by COVID-19 has a significant effect on humanity's physiological, social, and physiological components, particularly its health. Shortwave UV light is one of the particular disinfectants on light-based technologies to inactivate coronavirus and has the ability to clean polluted air and surfaces that play a significant role in disease transmission. The single-stranded RNA virus known as SARS-COV-2 is a member of the Coronaviridae family. RNA viruses can be inactivated by light-based cleaning techniques in a variety of matrixes. SARS-COV viruses have many structural similarities with coronaviruses, making them both extremely UV sensitive. Numerous ultraviolet products, including ultraviolet germicidal irradiation (UVGI), are suggested for use as disinfectants to clean up various settings and surfaces infected with the SARS-COV virus. Deep ultraviolet light-emitting diode (DUV-LED) is another UV light disinfection product that has the capacity to inactivate the SARS-COV to halt the spread of COVID-19. It is a technique with the capacity to offer virus inactivation that is energy-efficient, contact-free, and devoid of any residual compounds after treatment. It also has very little impact on targets and is adaptable to many virus variations. According to prior experimental research of several peer-reviewed articles, it requires a maximum exposure of 15 minutes in UV radiation and a distance of up to 1 m from the UV emitter to completely inactivate coronaviruses, including SARS-COV-2. Hospitals and other public spaces can employ these UV radiation-based IPC systems.

Keywords: IPC systems, coronaviruses, light-emitting technologies, disease transmission

Introduction

Coronaviruses are a broad family of respiratory viruses that contains COVID-19. COVID-19 is a single-stranded (positive sense) RNA virus that is housed in spherical or pleomorphic enclosed particles. Within a capsid, the RNA is bound to a nucleoprotein, and the envelope has club-shaped glycoprotein projections. Coronaviruses are classified as the subfamily Coronaviridae of the family Coronaviridae and the order Nidovirales. This dangerous virus has created a pandemic situation and a red-flag global health concern around the planet. Disinfection and sterilization are critical for preventing the spread of this disease. To decrease the spread of this severe, lethal pathogenic virus, a successful disinfection strategy combined with additional infection-preventing countermeasures may have helped. Photobiomodulation, a light-based anti-inflammatory therapy, may help alleviate symptoms of severe COVID-19 (Mancini, Almeida-Lopes, Jacinto, Tsukamoto, & Arns, 2022) [6]. This review explores how light-based technologies can prevent and regulate COVID-19 infection through viral inactivation, as well as treat it by influencing the immune system. UV radiation has particularly powerful germicidal effects on coronavirus transmission since it is ubiquitously and naturally generated by the Sun and accounts for 10% of total sunlight output. Only a limited amount of sunlight contains direct antibacterial characteristics or UV-C. This sunlight spectra are particularly useful in the decontamination of aerosols and surfaces; nevertheless, the efficiency of UV-C is highly reliant on-air relative humidity. Healthcare institutions use two types of UV radiation technologies: pulsed xenon UV and steady-state UVC generating systems. The pulsed xenon UV emits a broad spectrum of UV radiation (100-280 nm) and visible light (400-700nm) (Unal *et al*., 2021) [11]. They require frequent repositioning inside the room. This increases the amount of time and effort required for disinfection.

Continuous wave UVC devices, on the other hand, emit UV radiation with a wavelength of 253.7nm, which is readily absorbed by nucleic acids and thus more effective in destroying bacteria. The UVC disinfection procedure reduces viral infection by 44% and is more convenient than other processes. As a result, UVC is an important approach for both regulating viral transmission from surfaces and lowering bacterial bio burden (Raeiszadeh & Adeli, 2020; Sabino *et al*., 2020) [8, 10].

Importance of UV disinfection

Ultraviolet disinfection has been an established technology for decades, and it is used to disinfect surfaces, air and water. The UV-C spectrum (200-280 nm) contains germicidal action. UVC radiation has a negative effect on microbial cells because it is absorbed by microorganisms' internal components such as DNA, RNA, and proteins (Koivunen & Heinonen-Tanski, 2005) [3].
UV radiation inactivates viruses that contain single stranded nucleic acid (ssDNA or ssRNA) more than viruses that have double stranded nucleic acid. UV-C has the capacity to inactivate more than 99.9% of SARS-CoV-2 virus particles, and with sufficient exposure, it has the same germicidal effects as ethanol, dry heat, or vaporized hydrogen peroxide. The far-UV-C (207-222nm) spectrum is considered safe for human exposure and has potential as a disinfectant (Guo, Pan, Chan, Ho, & Chen, 2023) [2].
The mechanism underlying the prevention is that as the adenine-thymine bond collapses, a covalent linkage, pyrimidine dimer, is formed between the two adenines, preventing cell multiplication. That is why UV-C is used to 'inactivate' germs rather than kill them. However, in the case of virus infectivity and virion nucleic acid, increasing exposure to ambient UV accelerates viral mutation. However, the deadly effect of UV-induced nucleic acid (DNA or RNA) damage is highly reliant on the location of alterations in the viral genome. Many mutations can be identified after they are fixed by the host repair mechanism. Some alterations also result in the emergence of more harmful viruses, such as UV-resistant strains. UV disinfection is an energy-based procedure in which the inactivation ratio is governed by the UV radiation applied through the disinfecting unit. The UV dose is the amount of irradiance or fluence delivered to the microbial cells. UVC sources are used in both industry and academic research cases (Ma *et al*., 2021) [5].

Viral mutation technique

Viral genome mutation is a major cause of disease transmission. There are two forms of viral mutations: antigenic shift and antigenic drift, which reduce vaccine efficacy. Antigenic shift is more detrimental because, once the shift happens, mutant viruses are more likely to create a pandemic due to a lack of immunity to that specific strain of virus. For example, the change in the genome of SARS-CoV-2 renders the acute respiratory illness caused by the virus difficult to treat. On the other hand, the delta version of SARS-CoV-2 spreads up to three times faster than the original strain. As a result, it can more effectively infiltrate the host cell and suppress the immune system. The spike protein D614G improves entrance into cells by increasing the protein density on the surface. To prevent the spread of the disease, mutant strains should be eliminated before they can infect a host; they cannot replicate, mutate, or spread (Browne, 2021; Ozono *et al*., 2021; Zhang *et al*., 2021) [1, 7, 12].

UV microbial radiation inactivation mechanism

UV light can destroy some viral capsid proteins. Protein damage is slower than nucleic acid damage at 280nm. UV light primarily modifies protein structures and exposes the hydrophobic portion of the protein, resulting in protein unfolding or aggregation. Additionally, when exposed to UV radiation, viral RNA undergoes covalent bonds. That is how UV radiation works in the case of nucleic acids and proteins. SARS-CoV-2 is an RNA virus that contains RNA, which aids in defining the pathogen's response to ultraviolet radiation based on its genomic structure and chemistry. SARS-CoV-2 is genetically similar to SARS-CoV-1, making it a significant risk factor for UV radiation damage. Both of these viruses are positive sense RNA encapsulated viruses. Although the CoV family is slightly more resistant to UV radiation than other bacterial species such as Escherichia coli. The CoV family's response to UVC radiation is comparable to known benchmark viruses such as bacteriophage MS2, which is typically more UV sensitive. On the other hand, SARS-CoV-1's resistant behavior necessitates a greater UV dosage to complete the inactivation process. Thus, UV light can inactivate SARS-CoV-2. The regulatory health agencies establish the appropriate UV dose and level of inactivation for the unique CoV. Due to the BSL or biosafety level issue, testing such harmful germs as SARS-CoV-2 can be difficult, and SARS-CoV-2 is likely to be classified alongside SARS-CoV-1 as a weakly resistant virus to UV radiation that requires a high UV level for complete disinfection. UV dosages above 20mJ/cm² often result in a 99.9% reduction. However, for SARS-CoV-2, doses of 20mJ/cm² and 40mJ/cm² of 254nm UVC are sufficient for 4-log and 6-log inactivation (Kowalski 2010; Rothman & Setlow, 1979; Zhao, Traganos, & Darzynkiewicz, 2010) [4, 9, 13].

Conclusion

The COVID-19 pandemic is a global health concern, and it has afflicted individuals all over the world, creating an emergency situation. It is critical to take care and use various disinfectants to ensure that the environment is free of pollution. UV radiation disinfection is one of the most effective procedures and is widely utilized in the COVID-19 condition to reduce disease spread. These strategies may assist high-risk locations in both SARS-CoV-2 and SARS-CoV-1 outbreaks.

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