Germicidal Ultraviolet (GUV): A Powerful Tool for Improving Indoor Air Quality and Reducing Disease Transmission

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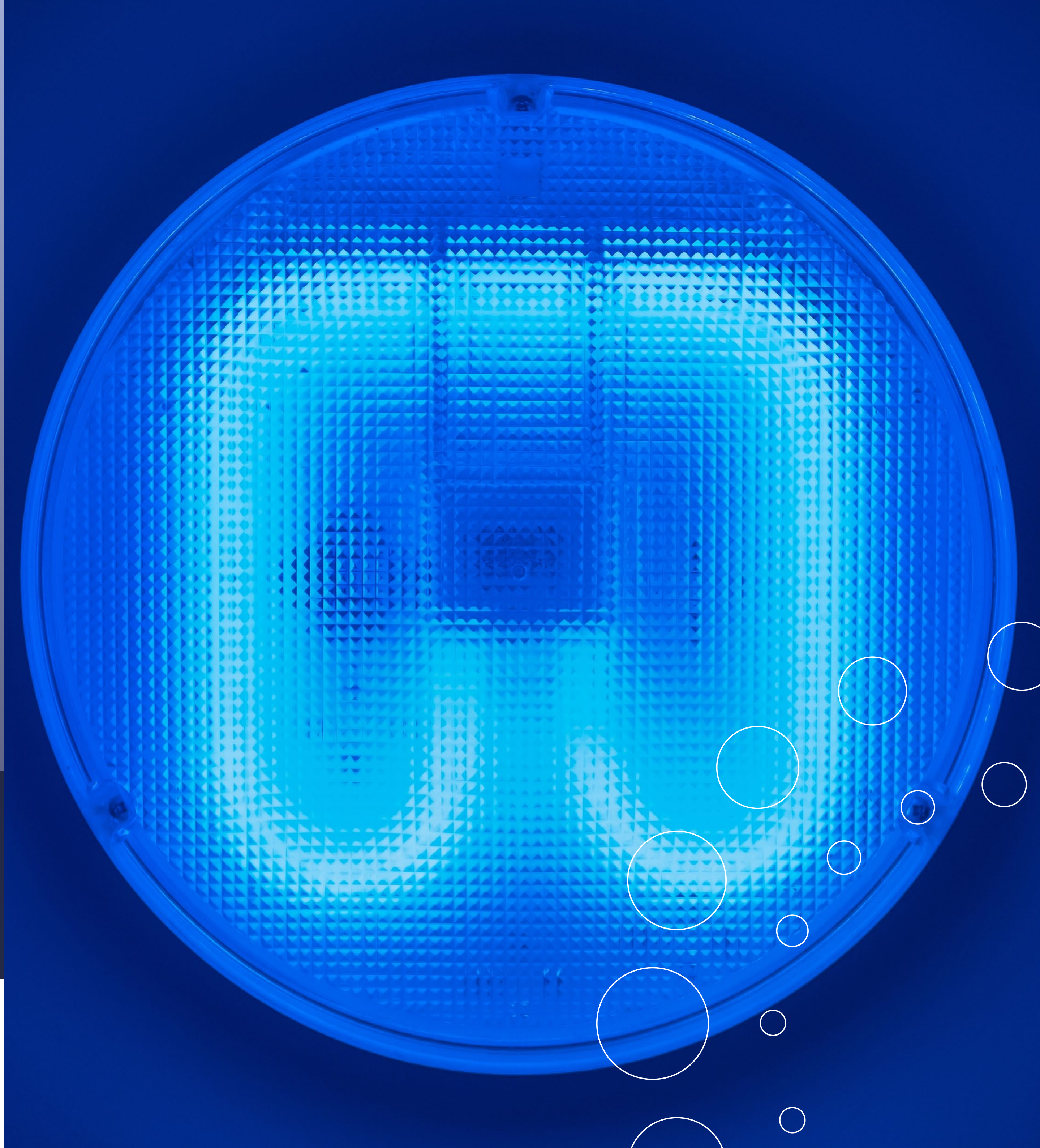

Scientia

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The COVID-19 pandemic highlighted the critical importance of indoor air quality for public health. Dr P Jacob Bueno de Mesquita from Roger Williams University is part of a growing community of scientists dedicated to studying and implementing germicidal ultraviolet (GUV) technology to reduce the transmission of airborne pathogens. This work has the potential to dramatically improve air quality in indoor spaces and mitigate the spread of respiratory infections like COVID-19, influenza, RSV, common colds, and tuberculosis.

The Hidden Danger of Shared Air

When thinking about staying healthy, the public often focuses on factors like diet and exercise. But an invisible threat surrounds us every day: the air we breathe. The air in our homes, offices, schools, and other buildings can harbour dangerous pathogens that cause respiratory infections.

The COVID-19 pandemic highlighted this issue, as it became clear that the SARS-CoV-2 virus could spread efficiently through the air in indoor spaces, leading to large superspreading events and the continued circulation and evolution of the virus in the population. But COVID-19 is not the only airborne threat we face. Common, dangerous illnesses like influenza and tuberculosis – major global health concerns – also spread through the air we share indoors. Rhinovirus outbreaks in schools are linked with increases in population-level asthma exacerbation.

Traditional methods for improving indoor air quality, such as increased ventilation and air filtration, can help reduce the concentration of airborne pathogens. However, these approaches have limitations. Ventilation systems are often inadequate, especially in older buildings, and can be expensive to upgrade. High-efficiency air filters can be effective but may not capture the smallest virus-carrying particles. However, even highly functioning ventilation and filtration systems do not provide efficient enough air cleaning to mitigate potential superspreading events.

The Power of Germicidal Ultraviolet Light Technology

Germicidal ultraviolet (GUV) light technology occurs in specific wavelengths that can inactivate microorganisms, including viruses, bacteria, and fungi. This is not UVA or UVB that can penetrate and damage the eye and skin but uses a lower wavelength of light in the UVC spectrum that is dramatically safer. But even still, classic GUV units are installed in rooms overhead where people cannot inadvertently look at them. Newer GUV uses an even lower and safer wavelength in the UVC spectrum and can be shined down into a space with occupants, allowing for direct disinfection in the breathing zone. When properly implemented, GUV systems can effectively clean indoor air, dramatically reducing the concentration of infectious particles.

Dr P Jacob Bueno de Mesquita at Roger Williams University is leading research into the applications of GUV technology. His work, along with that of collaborators worldwide, is helping to demonstrate the enormous potential of GUV as a tool for protecting public health.

The Science Behind GUV

Ultraviolet light falls between visible light and X-rays on this spectrum. Based on wavelength, it's further divided into three categories: UVA, UVB, and UVC.

GUV technology primarily uses UVC light, which has the shortest wavelength and highest energy of the three types. This high-energy light can damage microorganisms' genetic material (DNA or RNA), preventing them from replicating and effectively rendering them harmless.

Traditional GUV systems have used mercury lamps that emit light at a wavelength of 254 nanometres (nm). However, newer technologies, including LED-based systems and excimer lamps that emit light at even shorter wavelengths, such as 222 nm (known as far-UVC), have arrived and are beginning to be used widely. It is thought that far-UVC not only renders viruses and

bacteria non-infectious via disruption of their genome but also via disruption of their outer membrane proteins.

Proving the Effectiveness of GUV

One key challenge in implementing GUV technology is demonstrating and communicating its effectiveness in real-world settings. Dr Bueno de Mesquita and his colleagues have been working to address this challenge through rigorous scientific studies.

A groundbreaking study by Dr Ewan Eadie and colleagues provided compelling evidence of GUV's potential. The researchers set up an experimental room-sized chamber to simulate real-world conditions. They used far-UVC lamps (222 nm) and introduced an aerosolised bacterium (*Staphylococcus aureus*) into the air.

The results were striking. With all five lamps operating at their highest setting, the steady-state pathogen load in the air was reduced by 98.4% compared to using ventilation alone. This level of air cleaning was equivalent to providing an additional 184 equivalent air changes per hour – a remarkable improvement in air quality that would be virtually impossible to achieve through traditional ventilation methods.

The air changes per hour quantifies the number of times air the volume of a space enters the space in an hour. For comparison, in typical commercial buildings, a highly functioning HVAC system may deliver something like 3-5 ACH, and 12 ACH is used in negative pressure healthcare facilities. A Corsi-Rosenthal box filter might deliver something like another 3-5 ACH, depending on the room size. So, a room – say a university classroom – with good HVAC and a box filter might have 10 ACH in a good scenario. But we need an ACH for each infectious dose shed into the air by those who are infected (many are very contagious before symptoms even begin!). We know that contagious influenza and coronavirus cases can shed dozens to hundreds of infectious doses into the air per hour, so we know we need an equivalent amount of ACH. GUV is the only technology that offers equivalent ACH at such a level to mitigate key spreading events while people gather at school, work, public transit, cafes, restaurants, bars, gyms, dance clubs, places of worship, etc.

Importantly, this high level of pathogen reduction is achieved with UVC levels below the current conservative safety guidelines for human exposure. This demonstrates the remarkable safety profile for far-UVC technology used continuously in occupied spaces, providing ongoing protection against airborne pathogens.

One significant contribution from Dr Bueno de Mesquita's team is the ongoing comprehensive analysis of far-UVC's effectiveness in real-world settings. Their research, conducted in collaboration with other leading scientists, is poised to demonstrate in simple, visually compelling terms to the general public and key stakeholders that far-UVC can provide viral airborne transmission protection well exceeding traditional ventilation and filtration methods. This may be our only way to maintain some semblance of normal human societal interaction and harmony during seasonal epidemics and emerging pandemics. This is particularly important in settings where high air change rates are necessary to mitigate the risk of airborne transmission.

Addressing Potential Concerns

Any technology that involves exposing people to ultraviolet light must be carefully evaluated for safety and Dr Bueno de Mesquita and colleagues have been working to assess and mitigate any potential risks associated with GUV technology.

Traditional UVC light at 254 nm can cause skin irritation and eye damage with direct exposure. For this reason, these systems are typically used in upper-room configurations or in air-handling units, away from direct human contact. However, the newer far-UVC technology (222 nm) appears to have a much better safety profile.

Studies have shown that 222 nm light does not penetrate beyond the outer dead layer of human skin or the tear layer of the eye, meaning it can potentially be used more freely in occupied spaces. However, Dr Bueno de Mesquita emphasises that ongoing research is crucial to fully understanding this technology's long-term safety.

To this end, Dr David Welch and his team at Columbia University have conducted detailed studies on the safety of far-UVC light. They recently used specialised film dosimeters to measure human exposure to far-UVC in real-world settings. Their findings suggest that actual exposure levels are typically much lower than the maximum permissible exposure limits, providing further evidence for the safety of this technology.

Applications in High-risk Environments

While GUV technology has potential applications in various indoor environments, it may be particularly valuable in high-risk settings where disease transmission is a significant concern. One such setting is prisons, where overcrowding and poor ventilation can create ideal conditions for the spread of airborne pathogens.

Dr Bueno de Mesquita was involved in a comprehensive study of COVID-19 transmission in California state prisons. As part of this work, he and his colleagues evaluated the potential impact of various interventions, including GUV technology.

Their analysis suggested that implementing GUV systems in prison housing units could significantly reduce the risk of disease transmission. In some scenarios, GUV was estimated to provide the equivalent of over 100 air changes per hour – a level of air cleaning that would be virtually impossible to achieve through traditional ventilation methods.

The Future of GUV Technology

As research continues to demonstrate the effectiveness and safety of GUV technology, Dr Bueno de Mesquita and his colleagues are looking to the future. They see enormous potential for GUV to become a standard feature in buildings, much like smoke detectors or fire sprinklers are today.

One exciting area of development is the integration of GUV with other building systems. For example, GUV could be combined with smart building technology to optimise its operation in the areas where it's most needed based on occupancy patterns and air quality measurements. This could help ensure maximum effectiveness while minimising energy use and human exposure.

Another promising direction is the development of portable or personal GUV devices. These could provide protection in settings where permanent installations are not feasible or for individuals who are at particularly high risk of infection.

Dr Bueno de Mesquita and his team are also planning further studies to quantify the real-world effectiveness of GUV technology in various settings. They have received funding to conduct a dosimetry study on their university campus, which will monitor exposure to both 254 nm and 222 nm GUV fixtures. This study will provide valuable data on the effectiveness and safety of GUV in an educational setting.

Challenges and Opportunities

Despite its potential, the widespread adoption of GUV technology faces several challenges. One is the need for clear guidelines and standards for its implementation and training for a workforce of electricians and engineers who do the installations. Dr Bueno de Mesquita and his colleagues are working with professional organisations and regulatory bodies to develop these standards.

Another key challenge is public perception and understanding of the technology. Many people may be wary of anything involving ultraviolet light, associating it with sunburn and skin cancer. Education and outreach will be crucial to help people understand the differences between harmful UV exposure from the sun and the controlled, safe use of GUV for air disinfection. Others raise concerns about the production of ozone, although normal ventilation rates appear sufficient for mitigating potential secondary chemistry. Researchers have shown that real world GUV installation yields indoor ozone levels lower than those outdoors.

Cost is also a consideration, particularly for retrofitting existing buildings with GUV systems. However, Dr Bueno de Mesquita points out that when compared to the costs of disease outbreaks – both in terms of human life, health, and societal economic impact – GUV technology proves to be a highly cost-effective intervention.

A Powerful Tool for Public Health

GUV technology offers a powerful tool for improving indoor air quality and reducing disease transmission. This exciting research is helping to build the scientific foundation for the widespread adoption of this technology.

By harnessing the power of ultraviolet light, we may be able to create indoor environments that are significantly safer and healthier. This could have far-reaching implications for public health, reducing the burden of respiratory infections, improving the quality of life of millions of people, and enabling physical human interaction when epidemics and emerging pandemics threaten the closure of public spaces.

With continued research and development, GUV technology could be crucial in creating a healthier,
more resilient society. As we look to the future, the invisible threat of airborne pathogens may be met with an equally invisible but powerful defence: the disinfection power of ultraviolet light.

MEET THE RESEARCHER

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Dr P Jacob Bueno de Mesquita is an Assistant Professor in the Department of Public Health at Roger Williams University. His research focuses on improving environmental health and harmony and training students in key methods to advance population health and justice. His work spans science communication on the power of plant-based foodscapes, air cleaning strategies (focusing on germicidal ultraviolet technology – GUV) to mitigate airborne viral epidemics and pandemics, to the promotion of healthy and sustainable built environments more broadly. Dr Bueno de Mesquita's work spans from laboratory studies of influenza transmission to real-world applications of air-cleaning technologies in schools, prisons, and other settings. He has contributed to groundbreaking research on the effectiveness of quantifying transmission of influenza and is working on quantifying and communicating the benefits of GUV for inactivating airborne pathogens and developing guidelines for its safe and effective implementation. Dr Bueno de Mesquita is also passionate about sustainable building design and its impact on health. His interdisciplinary approach combines epidemiology, aerobiology, and environmental health sciences, along with graphic design, communications, and policy. Dr Bueno de Mesquita received post-bacceloreate training at the Centers for Disease Control and Prevention, his PhD from the University of Maryland School of Public Health, and he completed postdoctoral training at both the University of Maryland and Lawrence Berkeley National Laboratory.

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