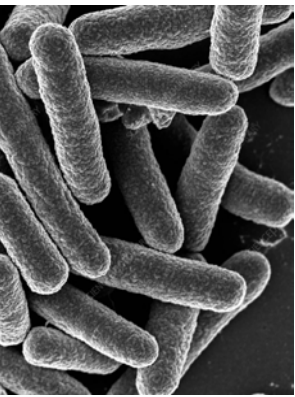


Daylight through Smart Windows Sterilizes Harmful Pathogens

EXECUTIVE SUMMARY



Nearly 150 years ago, a pair of pathologists made an incredible discovery: sunlight inhibits the growth of bacteria. This breakthrough discovery led to many advancements in the treatment and prevention of bacterial diseases, such as the Nobel Prize-winning treatment of skin tuberculosis using the Finsen lamp in 1903. We now know that daylight inactivates not just bacteria but also many viruses and fungi including SARS-CoV-2. UV light technologies have been adapted to sterilize everything from water to surgical rooms to escalator railings. However, UV comes with the downside of discoloring fabrics, degrading certain mechanical equipment, increasing the risk of skin cancer and bringing in excessive heat indoors. As a result, modern windows block UV light, begging the question: What is the effect of daylight on pathogens indoors?

Methods

Dr. Sepideh Pakpour, Director of the Pakpour Microbiome Laboratory at the University of British Columbia, designed a highly controlled chamber to test the effect of daylight on bacterial and fungal growth:

- View Smart Windows, in their clear state (Tint 1; 60% light transmittance)
- View Smart Windows, in their tinted state (Tint 4; 1% light transmittance)
- Blinds, with windows in their clear state (1% openness factor; 1% light transmittance)

The chamber allowed the researchers to control other factors such as temperature, humidity and airflow. Cultures of pathogenic bacteria and fungi were placed into the chamber and their viability and growth under these daylight conditions were measured.

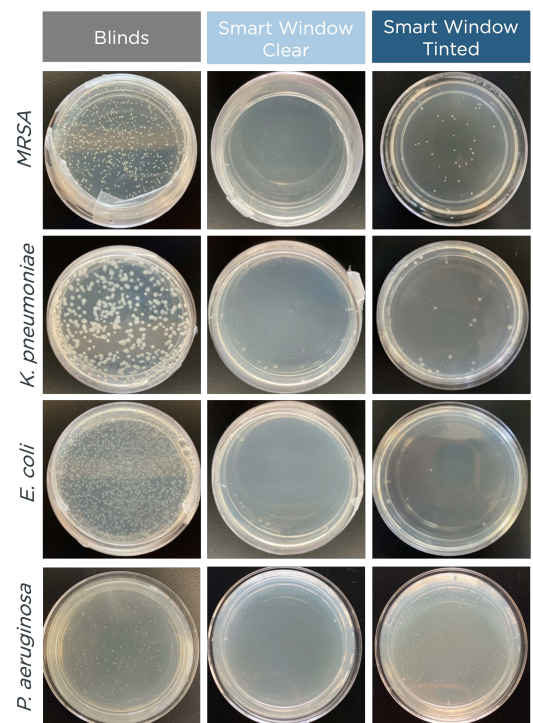


Key Findings

Smart windows caused a complete 100% reduction of bacteria and fungi in their clear state compared to traditional windows with blinds. When in their darkest tint state, bacteria were reduced by 41-100% and fungi by 26-42% depending on the level of nutrients available and surface material.

Conclusions

Harnessing daylight as a natural disinfectant is a powerful strategy to reduce contamination – and thus reduce the risk of disease transmission – in indoor spaces. This can have particularly important consequences in spaces where providing a contaminant-free space is paramount: In a hospital, reducing surface contamination is key to mitigating the risk of healthcare-associated infections, which can cost millions of dollars and thousands of preventable deaths per year; in a laboratory setting, it is a critical consideration for quality assurance and regulatory compliance.



View Smart Windows cause nearly complete disinfection of harmful bacteria, as evidenced by the number of colonies formed.



INTRODUCTION

Ventilation and surface disinfection protocols are readily understood to play a massive role in maintaining a healthy indoor microbiome and controlling the spread of infectious disease indoors. But what about daylight?

Light is another environmental factor that is well-understood to impact the growth and viability of bacteria and fungi. Decades of research have demonstrated the antimicrobial effects of the ultraviolet (UV) spectrum of light - leading to the development of UV lamps and other technologies for surface disinfection. However, less is known about the impacts of natural daylight indoors - daylight passing through windows designed to filter out UV due to the harmful consequences it can have on skin and eye health. More recently, research has uncovered that the short wavelength spectrum of visible light (blue light), present in daylight, also has antimicrobial properties.

Indoor daylight is not only important in promoting occupant wellbeing through circadian rhythm, mental health and productivity, but also holds the potential to be a naturally-occurring, passive disinfection strategy that helps maintain a healthy microbiome in our indoor spaces. With traditional windows, however, blinds or shades are pulled down to control for heat and glare, ultimately blocking the disinfecting properties of daylight. Smart windows, by optimizing for daylight access across the day, maximizes our ability to harness this natural disinfectant.

THE EXPERT



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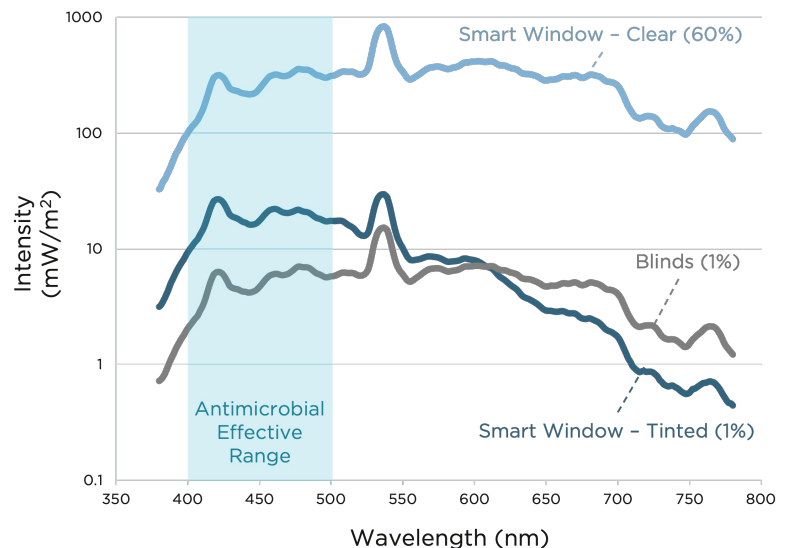


METHODS

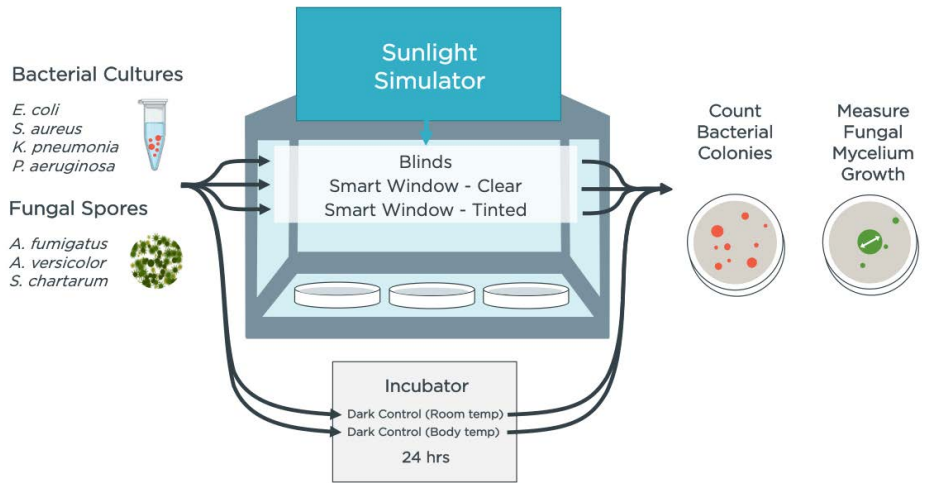
The experiments were conducted within a controlled chamber enclosed with panels of View Smart Windows. Conditions inside the chamber were designed to mimic a real indoor environment, with regulated airflow, temperature (-75°F) and humidity conditions (-40% RH), and a sunlight simulator which illuminated the inside of the chamber with the light spectrum representative of natural daylight.

- View Smart Windows, in their clear state (Tint 1; 60% light transmittance)
- View Smart Windows, in their tinted state (Tint 4; 1% light transmittance)
- Blinds, with windows in their clear state (1% openness factor; 1% light transmittance)

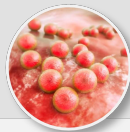
When the sun directly shines on a window, occupants likely pull down the blind to control for heat and glare. Alternatively, a smart window would convert to its tinted state. As indicated in the graph below, while both control systems reduce light transmittance to 1%, the light is differentially filtered across the spectrum. The fabric blind filters out the entire spectrum of daylight relatively equally, while View Smart Windows filter out more of the longer wavelength light and allows more of the shorter wavelength light to pass through.



Cultures of bacteria and spores of fungi were then placed into the chamber and their growth under these three daylight conditions were measured over the course of 24 hours (bacteria) and 72 hours (fungi). Bacterial strains were studied on both nutrient-rich (agar) media as well as nutrient-poor surfaces (plastic, glass and PVC fabric). All trials were conducted in triplicate. The bacteria and fungal species studied were selected due to their pathogenic nature and common occurrence on indoor surfaces.



BACTERIAL SPECIES



Staphylococcus aureus (MRSA)
+ (gram-positive)

Skin infection, can lead to serious bloodstream infection



Escherichia coli
- (gram-negative)

Diarrhea, food poisoning, acute kidney failure



Klebsiella pneumoniae
- (gram-negative)

Pneumonia, bloodstream infection, surgical site infections



Pseudomonas aeruginosa
- (gram-negative)

Pneumonia, blood infection, surgical sites infections

FUNGAL SPECIES



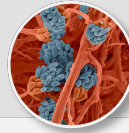
Aspergillus Fumigatus

Most common cause of aspergillosis



Aspergillus Versicolor

Produce numerous mycotoxins and also causes aspergillosis and onychomycosis



Stachybotrys Chartarum

Also known as "black mold", commonly associated with sick building syndrome

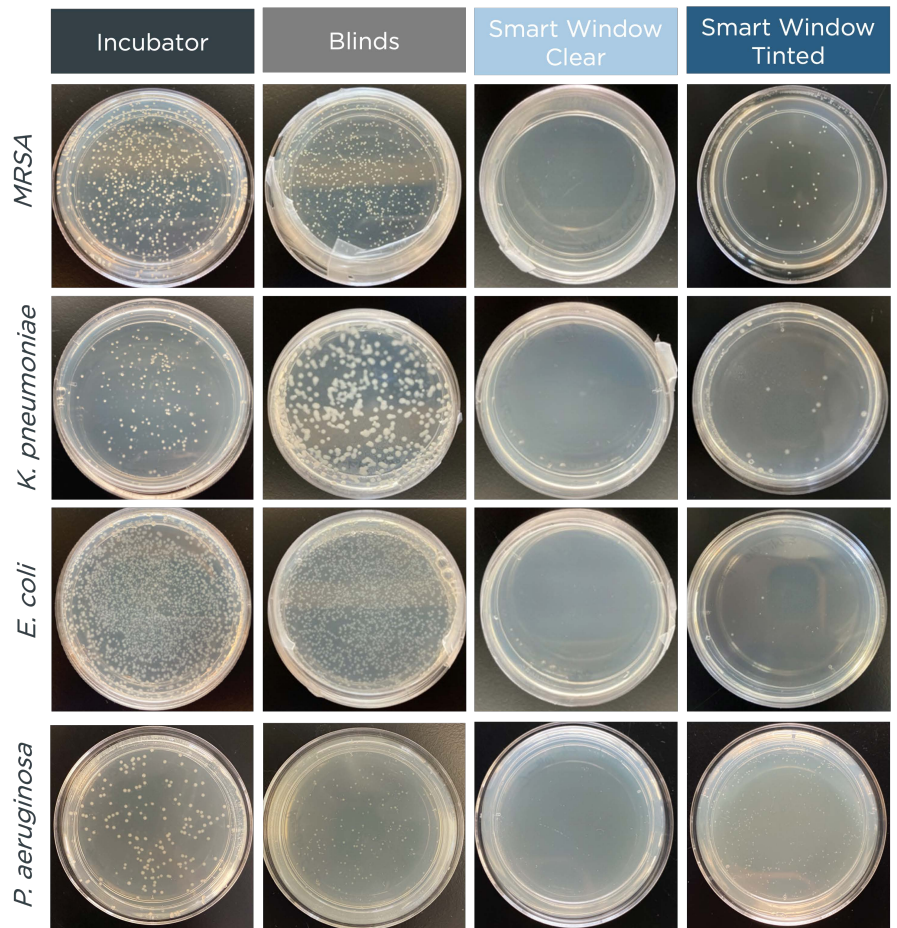
RESULTS

Smart windows let in more higher energy, shorter wavelength light – the range of visible light with antimicrobial effects – compared to traditional blinds, significantly reducing the viability of pathogens.

Bacteria

Daylight passing through smart windows in their clear state significantly reduced the viability of all tested bacteria when colonized in a nutrient-rich environment (i.e., food), with all tested bacteria demonstrating a >98% reduction relative to blinds. Daylight passing through the smart windows in their tinted state led to a 41-100% reduction in bacteria viability over 24 hours, relative to blinds. The highest reduction was observed in *E. coli* and *MRSA*, in which viabilities were reduced by 100% in both smart window conditions relative to blinds. Conversely, the Blinds condition was not statistically different than the incubator condition.

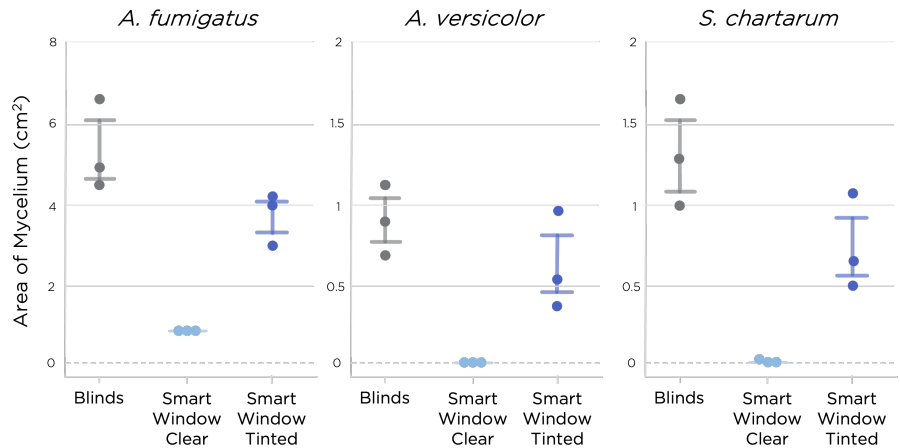
When the pathogens were cultured on different surface materials (plastic, glass, and PVC fabric), the results varied across material type but generally demonstrated the antimicrobial effects of daylight through smart windows relative to blinds. For example, daylight passing through smart windows in their tinted state reduced the viability of *MRSA* on PVC fabric by 100% and on glass by 78%, relative to blinds. The disinfection potential of PVC fabric, which is found in blinds and other furnishings, is particularly interesting as these are often the most difficult – and thus least frequently – cleaned surfaces with traditional cleaning agents yet are still frequently touched.



View Smart Windows cause nearly complete disinfection of harmful bacteria, as evidenced by the number of colonies formed.

Fungi

Daylight passing through smart windows in their clear state significantly reduced the growth of all tested fungal species, demonstrating a >86% reduction relative to blinds. Daylight passing through the smart windows in their tinted state led to a 26-42% reduction in fungal growth relative to the blinds condition with *S. chartarum* observing the highest reduction (42%).



IMPLICATIONS

Laboratory Environments

Microbial contamination is a major concern for life science companies - previous research reports that it is responsible for 11-15% of product recalls¹. In addition to the lost revenue and legal exposure, life science companies spend on average \$3.1M annually to remediate contamination events².

Passive surface disinfection with daylight can support laboratory environments to comply with Current Good Manufacturing Practices (cGMP) regulations to maintain a sterile laboratory environment, avoid remediation costs, and reduce the regulatory risk of FDA audits.

Healthcare Environments

Healthcare associated infections (HAIs) lead to nearly 100,000 deaths each year in the US and are commonly attributed to contamination of the patient's surroundings. Not only does a clean environment support healing and recovery - the primary role of the hospital - it can cost a hospital millions of dollars annually in CMS reimbursements. Hospitals that rank in the bottom quartile for the rate of HAIs face a 1% penalty on their CMS reimbursements.

With antimicrobial resistance increasing, treating patients post-infection is no longer a silver bullet. As these pathogens get harder to treat in the patient, the importance of treating them in the environment grows. Current approaches are burdensome and imperfect: for example, one study shows that 92% of blinds become recontaminated with MRSA within one week of cleaning³. Cleaning agents also pose a risk to patients and cleaning staff by releasing volatile organic compounds that can be irritants, allergens or asthmagens. Cleaning staff are 70% more likely to suffer from asthma due to chronic exposures to cleaning agents⁴.

1. Sutton & Jimenez (2012). A Review of Reported Recalls Involving Microbiological Control 2004-2011 with Emphasis on FDA Considerations of "Objectionable Organisms". *American Pharmaceutical Review*.
 2. 2012 Parenteral Drug Association (PDA) Environmental Monitoring Survey
 3. Ohl M, et al. (2012). Hospital privacy curtains are frequently contaminated with potentially pathogenic bacteria. *American Journal of Infection Control*, 40(10):904-906.
 4. Zock J, et al. (2001). Asthma risk, cleaning activities and use of specific cleaning products among Spanish indoor cleaners. *Scandinavian Journal of Work, Environment & Health*, 27,1, 76-81.

CONCLUSIONS

Harnessing daylight as a natural disinfectant is a powerful strategy to reduce contamination - and thus reduce the risk of disease transmission - in indoor spaces. This research shows that electrochromic windows bring in all the elements of daylight that can disinfect with none of the consequences of harmful UV light. Smart windows caused a complete 100% reduction in bacteria and fungi in their clear state and a 41-100% reduction in bacteria and 26-41% in fungi when in their darkest tint state. In comparison, traditional windows with blinds had a negligible effect with bacteria levels similar to the incubator. These findings signal the importance of designing offices, homes, hospitals and labs to bring in abundant natural light to reduce the risk of infectious disease transmission.