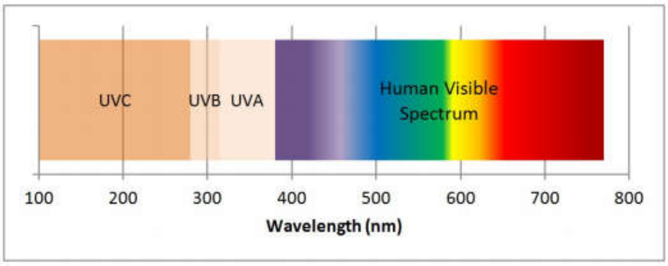
C6 - Disinfection Using Visible Light

Certain wavelengths of visible light exhibit antibacterial effects and can be useful for effective decontamination of air, working surfaces and fluids.

Background

Germicidal lighting has been in use for some time. This effective technology has been based around UVC lamps which are extremely dangerous to living organisms, including humans. Further they are incredibly destructive to many common materials, causing disintegration of plastics and rubbers and the pitting and cracking of metal surfaces.[1] One of the key discoveries of Full Spectrum Lighting is the ability for safe visible light to kill harmful bacteria with none of the nasty side effects of UVC light.

The cleansing function of sunshine is in some part due to the presence of UV light. Sunlight has negligible energy in the UVC range, and only a little in the UVB range, due to the filtering of the atmosphere. While UVC will kill bacteria in the upper atmosphere, it is not a 'natural' cleaning agent in the world in which we live. However, recent research[2] has shown that some wavelengths of visible light (~400nm to ~470nm) are also very effective in sterilising bacteria, including antibiotic resistant strains (MRSA, VRE and MDRA).



Reports have indicated that every year over 2 million Americans acquire serious drug resistant infections, and of those, at least 23,000 die and many more die from complications resulting from drug resistant infections. Apart from the human cost, the very real physical costs are considerable, and avoidable. Estimates for this cost in the US alone amount to $20 billion in direct healthcare costs and a further $35 billion in additional costs for society (due to lost productivity).[3]

The accepted theory as to why certain wavelengths of light can inactivate bacteria is that internal parts of the microbial cells are sensitive to radiant energy, and when energised they produce toxic oxidative chemicals, such as Hydrogen Peroxide (H_2O_2). Research has shown that this reaction occurs despite the bacteria's drug resistance, and the bacteria do not appear to be able to develop resistance to this type of attack.[4]

Host cells do not incur significant damage and wound healing is not impaired. Because mammalian DNA is unaffected by these wavelengths of visible light, it is safe for humans and animals, and can be used in general indoor lighting to provide a continual sterilizing effect, or simply to provide a cleaning function when areas are unoccupied.

Typical clinical trials have reported an 85% reduction in bacteria in operating theatres and a 73% reduction in the number of surgical site infections.[5] Numerous studies have shown both its effectiveness and its safety.

[1] A comparison study of the degradative effects and safety implications of UVC and 405nm germicidal light
[2] Initial studies by the University of Strathclyde, Scotland. Supporting studies by the U. North Carolina
[3] Report reveals scope of US antibiotic resistance threat. Hampton T. JAMA. 2013 Oct 23; 310(16):1661-3.
[4] The antimicrobial effect of blue light. Tainhing Dai. VIRULENCE 2017, VOL 8, No 6, 649-652
[5] Maury Regional Medical Centre, Columbia, Tennessee

Artificial indoor lighting has not historically contained any significant energy in these wavelengths, with the phosphors in the ubiquitous fluorescent light fitting predominantly producing two light peaks in the orange-red (Yttrium Oxide - 611nm) and green (Calcium Tungstate - 543nm) spectrums, with a small blue peak (Barium Aluminate - 450) in triphosphor tubes).

More recently, LED fixtures have used white LEDs, which while actually being blue LEDs (closer to 450nm), are coated in a phosphor to shift their spectrum emissions up into the areas of peak sensitivity of the human eye (green). This enables a more efficient light source as the spectrum more closely matches that of the human eye's sensitivity.

The human eye's sensitivity to blue light (for hormone production) is in the 470nm - 490nm range, while the disinfection properties of "blue" light is in the 400nm - 420nm range.

With the introduction of intelligent Full Spectrum Lighting, we can now offer indoor lighting that provides not only optimal photobiological stimulation at different times of day, but also natural levels of disinfection within working areas. With the ability to control the spectrum of the light source, we can deliver a light that looks "white" but actually contains parts of the spectrum tuned to provide optimal health and comfort outcomes.

Quick Summary of Current Research

Reference

The Scientific World Journal Volume 2012, Article ID 137805, 8 Pages

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3330698/

Bactericidal Effects of 405 nm Light Exposure Demonstrated by Inactivation of Escherichia, Salmonella, Shigella, Listeria, and Mycobacterium Species in Liquid Suspensions and on Exposed Surfaces

Murdoch LE, Maclean M, Endarko E, MacGregor SJ, Anderson JG.

Abstract

The bactericidal effect of 405 nm light was investigated on taxonomically diverse bacterial pathogens from the genera *Salmonella, Shigella, Escherichia, Listeria, and Mycobacterium*.

High-intensity 405 nm light, generated from an array of 405-nm light-emitting diodes (LEDs), was used to inactivate bacteria in liquid suspension and on exposed surfaces.

L. monocytogenes was most readily inactivated in suspension, whereas *S. enterica* was most resistant. In surface exposure tests, *L. monocytogenes* was more susceptible than Gram-negative enteric bacteria to 405 nm light when exposed on an agar surface but interestingly less susceptible than *S. enterica* after drying onto PVC and acrylic surfaces.

The study findings, that 405 nm light inactivates diverse types of bacteria in liquids and on surfaces, in addition to the safety advantages of this visible (non-UV wavelength) light, indicate the potential of this technology for a range of decontamination applications.

Reference

The Journal of Hospital Infection. Sept 2014. Vol 88. Issue 1. Pages 1-11

405nm light technology for the inactivation of pathogens and its potential role for environmental disinfection and infection control.

M. Maclean, K. McKenzie, J.G. Anderson, G. Gettinby, S.J. MacGregor.

Summary

Background

Although the germicidal properties of ultraviolet (UV) light have long been known, it is only comparatively recently that the antimicrobial properties of visible violet–blue 405nm light have been discovered and used for environmental disinfection and infection control applications.

Aim

To review the antimicrobial properties of 405nm light and to describe its application as an environmental decontamination technology with particular reference to disinfection of the hospital environment.

Methods

Extensive literature searches for relevant scientific papers and reports.

Findings

A large body of scientific evidence is now available that provides underpinning knowledge of the 405nm light-induced photodynamic inactivation process involved in the destruction of a wide range of prokaryotic and eukaryotic microbial species, including resistant forms such as bacterial and fungal spores. For practical application, a high-intensity narrow-spectrum light environmental disinfection system (HINS-light EDS) has been developed and tested in hospital isolation rooms. The trial results have demonstrated that this 405nm light system can provide continuous disinfection of air and exposed surfaces in occupied areas of the hospital, thereby substantially enhancing standard cleaning and infection control procedures.

Conclusion

Violet–blue light, particularly 405 nm light, has significant antimicrobial properties against a wide range of bacterial and fungal pathogens and, although germicidal efficacy is lower than UV light, this limitation is offset by its facility for safe, continuous use in occupied environments. Promising results on disinfection efficacy have been obtained in hospital trials but the full impact of this technology on reduction of healthcare-associated infection has yet to be determined.

Reference

https://www.ncbi.nlm.nih.gov/pubmed/19065556
US National Library of Medicine, National Institutes of Health.
Lasers Surg Med. 2008 Dec.

Visible 405 nm SLD light photo-destroys methicillin-resistant Staphylococcus aureus (MRSA) in vitro.

Enwemeka CS, Williams D, Hollosi S, Yens D, Enwemeka SK.

Summary

Background

Infections with MRSA remain a growing public health concern, prompting the need to explore alternative treatments instead of the on-going effort to develop stronger drug-based therapies. We studied the effect of 405 nm blue light on two strains of MRSA-US-300 strain of CA-MRSA and the IS853 strain of HA-MRSA-in vitro.

Methods

We cultured and plated each strain, following which bacteria colonies were irradiated with 0, 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 25, 30, 35, 40, 45, 50, 55, or 60 J cm(-2) energy densities-just once-using a Solaris superluminous diode (SLD) device. Specimens were incubated at 35 degrees C for 24 hours. Then, digital images obtained were quantified to obtain colony counts and the aggregate area occupied by bacteria colonies.

Findings

Blue light irradiation produced a statistically significant dose-dependent reduction in both the number and the aggregate area of colonies formed by each bacteria strain ($P<0.001$). Maximum eradication of the US-300 (92.1%) and the IS-853 colonies (93.5%) was achieved within 9.2 and 8.4 minutes of exposure, respectively. The longer the irradiation the more bacteria were eradicated. However, the effect was non-linear as increases of energy densities between 1.0 and 15 J cm(-2) resulted in more bacteria death than similar increases between 15 and 60 J cm(-2).

Conclusion

At low doses, blue light photo-destroys HA-MRSA and CA-MRSA in vitro; raising the prospect that phototherapy may be an effective clinical tool in the on-going effort to stem MRSA infections.

Reference

The Journal of Hospital Infection. Nov 2010. Vol 76. Issue 3. Pages 247-251

Environmental decontamination of a hospital isolation room using high-intensity narrow-spectrum light

M.Maclean, S.J.MacGregor, J.G.Anderson, G.A.Woolsey, J.E.Coia, K.Hamilton, I.Taggart, S.B.Watson, B.Thakker, G.Gettinby

Summary

The performance of a new decontamination technology, referred to as 'high-intensity narrow-spectrum light environmental decontamination system' (HINS-light EDS) was evaluated by a series of three studies carried out in a hospital isolation room used to treat burns patients.

The ceiling-mounted HINS-light EDS emits high-intensity 405 nm light which, although bactericidal, is harmless to patients and staff thereby permitting continuous environmental disinfection throughout the day.

Performance efficacy was assessed by contact agar plate sampling and enumeration of staphylococcal bacteria on environmental surfaces within the room before, during and after HINS-light EDS treatment.

When the room was unoccupied, use of HINS-light EDS resulted in ~90% reduction of surface bacterial levels and when the room was occupied by an MRSA-infected burns patient, reductions between 56% and 86% were achieved, with the highest reduction (86%) measured following an extended period of HINS-light EDS operation.

In an on/off intervention study, surface bacterial levels were reduced by 62% by HINS-light EDS treatment and returned to normal contamination levels two days after the system was switched off.

These reductions of staphylococci, including *Staphylococcus aureus* and meticillin-resistant *S. aureus*, by HINS-light EDS treatment were greater than the reductions achieved by normal infection control and cleaning activities alone. The findings provide strong evidence that HINS-light EDS, used as a supplementary procedure, can make a significant contribution to bacterial decontamination in clinical environments.