SHINING A LIGHT ON CONTINUOUS DISINFECTION

Ultraviolet (UV) light as a disinfection system in hospitals and healthcare facilities has a downside: as soon as the procedure is complete, recolonisation of the area by bacteria resumes. SGS Life Sciences and Kenall Manufacturing, present a system that aims to offer continuous protection, even while the area is occupied

The incidence of healthcare acquired infections (HAIs) has been reduced significantly in recent years, but remains a problem in most hospitals and healthcare facilities. Until now, efforts have focused on improving handwashing regimes, the use of antibacterial materials such as copper, better cleaning procedures and extensive education of staff and patients.

Less attention has been paid, however, to the transmission of pathogens via the environment, and given the rise of antibiotic resistant bacteria, there is increased impetus to improving environmental hygiene to prevent surgical site infections.

Technology that makes use of UV light for disinfection of entire rooms and operating theatres is not new, but to date this only has been utilised on a one-off or episodic basis. This has a drawback: bacterial recolonisation of the area begins as soon as the disinfection is complete. To overcome this issue, a system has recently been introduced onto the market, which uses special luminaires, allowing it to be operated in two different modes based upon whether the area is in use. Both modes are safe for human occupancy.

Visible light disinfection constantly emits a narrow spectrum of visible light at 405 nm to kill harmful bacteria in the environment – in the air and on hard and soft surfaces – safely, automatically and continuously.[1,2] The light is first absorbed by porphyrin molecules inside the bacteria, creating toxic and biocidal reactive oxygen species (ROS), which inactivates the pathogen.

The use of 405 nm visible light as a potential method for reduction or inactivation of bacteria in the environment has been the subject of academic interest since 2001. Originally developed by the University of Strathclyde in Glasgow, the system has two modes of operation: blue light mode, which operates while the room is not in use; and white light mode, in which the proportion of antimicrobial blue light is reduced while the room is in use. The proportion of white light to blue light varies according to the type of environment, but is chosen to ensure a high-quality of light for performing tasks.

Lighting maker Kenall Manufacturing, which has an exclusive licence for this technology, has used its expertise to design a luminaire using LED light sources and a specific lensing system to allow the blue and the white light to scatter and mix within the fixture, so that the light that is emitted appears homogenous. Automatic ceiling sensors are used to detect motion in the room where the system is installed, initiating a switch from blue to white mode when someone enters, and returning the lighting to blue mode when the room is empty. The lights are left on 24/7 ensuring a continuous bactericidal effect.

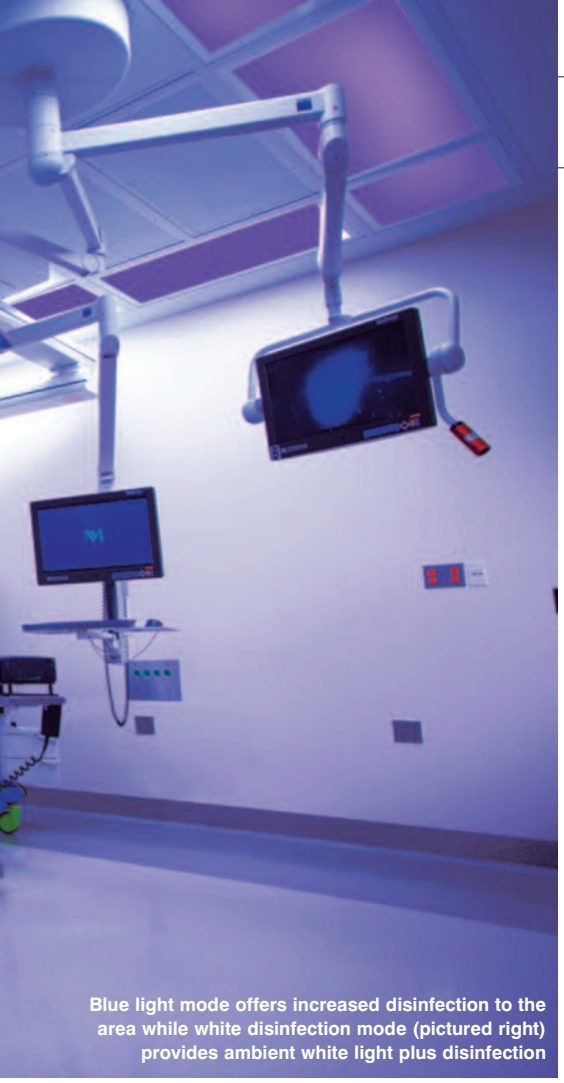
A unique feature of this system is that it uses visible light that scatters off the walls, floors and other surfaces, thereby reaching all areas of the room, even those not directly illuminated by the light overhead. As well as disinfecting hard and soft surfaces, it also kills airborne bacteria, reducing the overall bacteria level in the room as well as the precipitation of organisms onto surfaces, including surgical wounds.

The organisms most relevant in a hospital setting include *Enterobacter aerogenes, Staphylococus aureus, Klebsiella pneumonia, Acinetobacter baumannii, Pseudomonas aeruginosa*, and *Enterococcus faecalis* – the so-called ESKAPE group responsible for around 90% of nosocomial infections.

Disinfectant test

During the validation of the system, it was crucial to evaluate the capabilities in a laboratory, to assess the inactivation of medically important organisms on stainless steel surfaces. SGS Life Sciences investigated the susceptibility of a variety of medically-relevant Gram positive and Gram negative vegetative bacteria to 405 nm visible light. Initially, stainless steel coupons were used to execute the study, but there were issues with the viability of some of the organisms on the stainless steel coupons for extended periods of time.

Furthermore, the plating technique and any potential problems with organism



Blue light mode offers increased disinfection to the area while white disinfection mode (pictured right) provides ambient white light plus disinfection

recovery and enumeration from the surface of the coupon had to be taken into consideration. These two factors prevented SGS from properly assessing the efficacy of the light for all the microorganisms, and it therefore switched to what the company considered to be a worst case scenario and inoculated the organisms onto an agar surface.

The rationale behind this was that the media would supply an ideal environment for the organisms to grow, and if a reduction in the number of viable organisms on an agar plate could be seen in ideal conditions, then in theory, an equal level of organism kill/reduction would be seen on surfaces that were not as ideal for growth.

Bacteria, deposited onto the agar surface and the stainless steel coupons, were exposed to a high-intensity 405 nm visible light generated from a light-emitting diode array. The degree of bacterial inactivation was calculated by determining the number of surviving colony forming units (CFUs) after exposure to light at a predetermined distance and exposure times when compared with the controls that were not exposed to the bactericidal light.

The bacteria used in the study were *E. aerogenes* ATCC 13048, *S. aureus* ATCC 6538, *K. pneumoniae* ATCC 13883, *A. baumannii* ATCC 19606, *P. aeruginosa* ATCC 9027, and *E. faecalis* ATCC 19433. Dilutions of each microorganism suspension were prepared in phosphate buffer, such that 100 L contained approximately 200-300 CFU, and titered concurrent to test inoculations.

One of the fixtures from Kenall Manufacturing was used to create a uniform distribution of disinfecting light at a task plane 1.5 m beneath the fixture. This irradiance was measured at various points across the plane to be 0.498 mW/cm^2 to 0.558 mW/cm^2 using a National Institute of Standards and Technology (NIST)-calibrated portable spectrometer optimised for short wavelength measurements. All measurements were made over the spectral range 400-420 nm. The average irradiance was calculated to be 0.525 mW/cm^2 and was used for all calculations during the experiment. Agar plates (100 mm diameter) and stainless steel coupons (2.5 cm x 7.5 cm) were exposed to an average irradiance of 0.525 mW/cm^2.

Tryptic Soy Agar plates were inoculated with 100 L of bacteria and spread over the surface of the agar using a sterile spreader and then lids placed on the plates. The test plates were exposed to the light at a distance of 1.5 m for 24 hours. Non-exposed control plates were prepared for each light-exposed sample. After 24 hours, the test plates were removed and, along with the non-exposed control plates, were incubated at 30-35°C for at least 48 hours. Upon incubation, the plates were enumerated and results reported as CFU per plate. For varying exposure time study, the seeded plates were exposed to the light for 2, 6, 12, and 24 hours, whereas *E. faecalis* was exposed for 24, 48, 72 and 96 hours.

Similarly, stainless steel coupons were inoculated with 100 L of bacteria. The test coupons were exposed to the light at a distance of 1.5 m for durations of 4 and/or 24 hours. Non-exposed control coupons were also prepared for each light-exposed sample. Following exposure, the coupons were suspended in Fluid D and vortexed to recover bacteria from the coupons. Serial dilutions were prepared and plated using Tryptic Soy Agar. The test plates and non-exposed control plates were incubated at 30-35°C for at least 48 hours, and were enumerated with results reported as CFU per coupon (see Table 1 and 2 on next page).

The studies showed broad-spectrum activity of light against Gram positive bacteria such as *Staphylococcus aureus* and Gram negative bacteria such as *E. aerogenes*, *K. pneumoniae* and *P. aeruginosa* when seeded onto an agar surface. The bactericidal light was least effective against *E. faecalis* (Gram positive organism) and *A. baumannii* (Gram negative organism). When tested on a stainless steel surface, the significant light-dependent inactivation of population was observed with *E. aerogenes*, *S. aureus*, and *P. aeruginosa*, whereas least inactivation was observed with

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K. pneumoniae, *A. baumannii, and E. faecalis*. Among the group of Gram positive and Gram negative organisms, *E. faecalis* was found to be the least susceptible to inactivation by 405 nm light by other researchers.[1]

The inactivation data were comparable for *E. aerogenes, S. aureus, P. aeruginosa* and *A. baumannii* between agar surface and stainless steel surface. However, lowered reduction of population for *K. pneumoniae* was seen on the stainless steel surface when compared with the agar surface. *E. aerogenes, S. aureus, and K. pneumoniae* showed greater than 2-$\log_{10}$ reduction on the agar surface. Whereas *A. baumannii* and *P. aeruginosa* showed less than 2-$\log_{10}$ reduction. *E. faecalis* was the most resistant of the group showing negligible or least reduction in bioburden on the agar surface.

The effect of light-inducing inactivation of Bacillus and Clostridium spores has also been investigated and showed that although bacterial spores were sensitive to light inactivation, such reduction in spore population required a higher dose of light than that required for inactivation of vegetative cells.[3] In other studies, inactivation of yeasts and moulds due to lethal effects of light at 405 nm has also been investigated.[4]

Complementary action

As a result of the validation study by SGS Life Sciences, this new dual-mode system has been shown to achieve effective inactivation of medically important bacteria and thereby to offer the potential to provide continuous decontamination technology in a clinical setting.

The system is not intended as a replacement for conventional disinfection practices, nor does it act as a substitute for episodic disinfection during an infectious disease outbreak; but because it operates continuously it is complementary, reducing levels of reinfection. The technology is not effective against some types of organisms, such as viruses, however, it can kill *Clostridium difficile* endospores, which is a major concern in the patient environment because in this state it is resistant to many disinfectants.

Although aimed to be used primarily in operating theatres, the system could potentially be installed in patient bathrooms. Since many HAIs are gastrointestinal in nature, and patients spend relatively short periods in the bathroom, blue light mode would be operational for the majority of the time, ensuring prolonged sessions of intensive disinfection.

TABLE 1: THE GERMICIDAL EFFECT ON A RANGE OF BACTERIAL SPECIES SEEDED ONTO AGAR SURFACE AFTER 24 HOUR EXPOSURE TO 405 nm VISIBLE LIGHT

Bacteria	Exposed test plate CFU	Non-exposed control plate CFU	% Reduction	Log reduction
Enterobacter aerogeners	0	228	100	2.4
Staphylococus aureus	0	277	100	2.4
Klebsiella pneumoniae	0	240	100	2.4
Acinetobacter baumannii	45	304	85.4	0.8
Pseudomonas aeruginosa	6	113	95.1	1.4
Enterococcus faecalis	242	289	16.2	0.1

TABLE 2: INACTIVATION OF BACTERIA SEEDED ONTO AGAR SURFACE UPON EXPOSURE TO 405 nm VISIBLE LIGHT FOR DIFFERENT TIMES

LOG Reduction (% reduction)

Exposure time (hours)	*Enterobacter aerogeners*	*Staphylococus aureus*	*Klebsiella pneumoniae*	*Acinetobacter baumannii*	*Pseudomonas aeruginosa*	*Enterococcus faecalis*
2	0 (4.8%)	0 (0%)	0.3 (53.6%)	0 (0%)	1.2 (92.4%)	
6	1.1 (92%)	2.2 (99.3%)	1.5 (97.2%)	0.8 (85.3%)	2.0 (100%)	
12	1.5 (97.2%)	2.4 (100%)	2.3 (99.9%)	2.4 (99.7%)	1.9 (100%)	
24	2.6 (100%)	2.6 (100%)	2.2 (100%)	0.8 (83.1%)	1.9 (100%)	0 (0%)
48						0 (0%)
72						0 (0%)
96						0.1 (6.3%)

Additionally, an emergency department that is in constant use is difficult to shut down for episodic disinfection with a conventional UV device or a fogging system. It is also a high traffic area, so a constant bactericidal lighting system could reduce the level of organisms being taken through deeper into the hospital as patients are admitted to treatment areas. Walk-in clinics, outpatient departments, dialysis units and sterile compounding pharmacies are other potential users of the technology.

References

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