Investigating the susceptibility of laboratory-generated bacterial aerosols to antimicrobial 405nm light

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BACKGROUND AND AIMS

- Airborne transmission of infection is a major concern within the healthcare environment, with up to 20% of HAIs spread via the air.
- Traditional disinfection methods focus on surface contamination with little implemented to improve air quality.
- Ultraviolet (UV) light can be used for air disinfection, however there are operational limitations due to human safety issues.
- Visible light in the region of 405nm has wide antimicrobial efficacy and can be used as a method of 'whole room' environmental decontamination.
- This study aims to establish the dose response kinetics of airborne bacterial contamination exposed to 405 nm light and compare to UV-light.

SYSTEM METHODOLOGY

- *S. epidermidis* was nebulised into the test chamber using a 6 Jet Collison nebuliser with 12.5 L/min flow rate.
- Aerosolized bacteria were exposed to the germicidal light source.
- Air samples were removed from the chamber using a BioSampler liquid impinger.
- The collection liquid was serially diluted, pour plated, and surviving bacteria were enumerated.

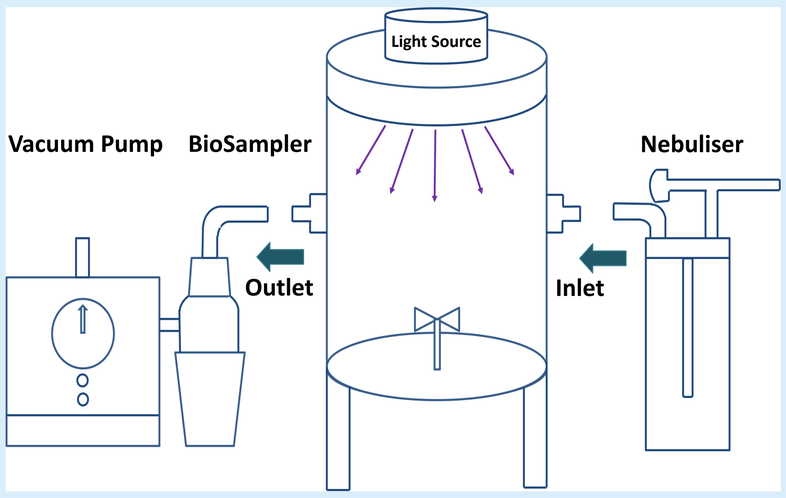

Fig 3. Experimental set up

CONCLUSIONS

- Aerosols of *S. epidermidis* were susceptible to low dose 405 nm light, however, improvements in the test system are required to reduce the impact of natural decay over extended exposures.
- Pulsed-UV light is highly efficient for decontamination of airborne bacteria.
- Although less germicially efficient, the benefits of 405 nm light provide increased safety for human exposure and whole room decontamination.

FUTURE WORK

- Increasing the irradiance of the 405 nm light sources to establish the potential for quicker inactivation.
- Investigation of aerosol dynamics to improve suspension inside the test chamber.
- Continuous-UV exposure of aerosolised *S. epidermidis* to further compare germicidal efficacy of light-based decontamination technologies.

LIGHT SOURCES

405 nm light: 405 nm LED array (PhotonStar Technologies) bonded to a heat sink and fan for thermal management with peak output close to 405 nm.

Pulsed-UV light: Low pressure 100W xenon filled flash lamp connected to a 1kV solid-state pulsed power generator (Samtech UK) with pulse frequency of 1Hz and output energy of 20 J/pulse when pulsed at 1 pulse/second.

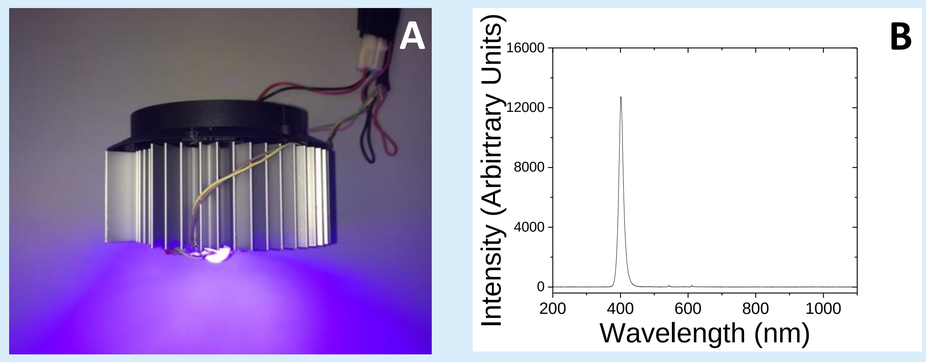

Fig 1. 405 nm LED array and (B) optical emission spectrum of 405 nm LED array.

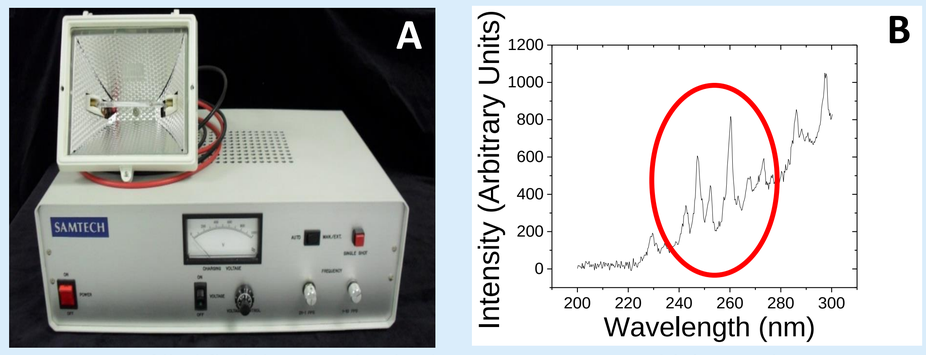

Fig 2. Xenon filled flash lamp and pulsed power generator and (B) UV-rich emission spectrum of xenon flash lamp.

405 nm RESULTS

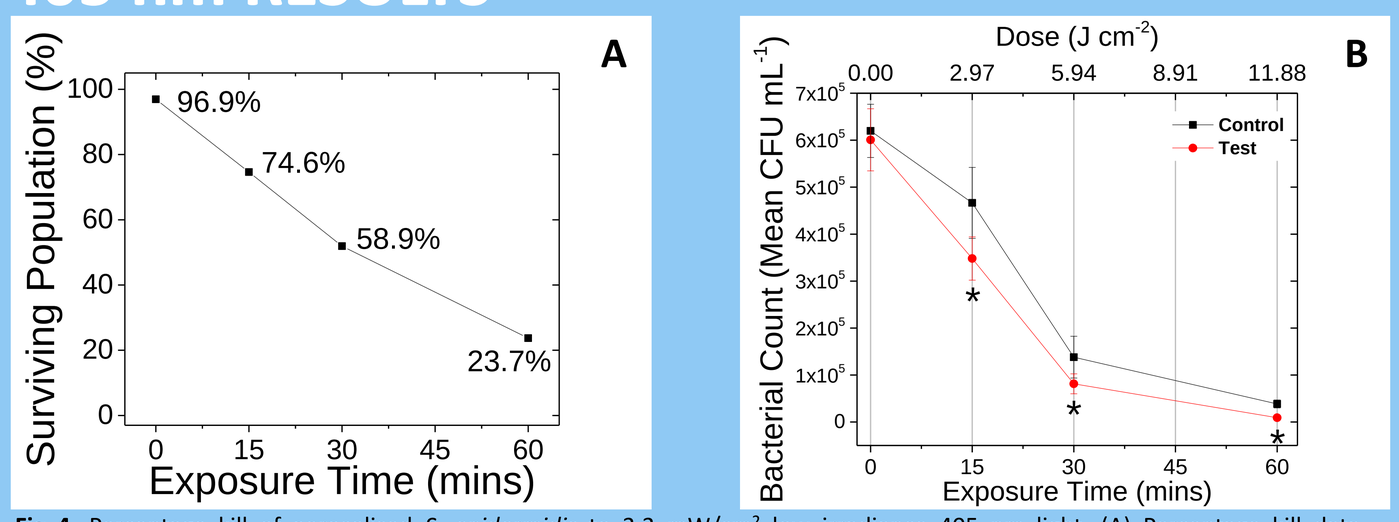

Fig 4. Percentage kill of aerosolised *S. epidermidis* to 3.3 mW/cm^2 low irradiance 405 nm light. (A) Percentage kill data compared to control and (B) dose-response kinetics (n≥9 ± SD).

- After a dose of 11.88 J cm^{-2} (60 min treatment), a 76.3 % reduction was observed (P= 0.00002).
- Significant reduction in airborne bacteria was achieved after an initial dose of 2.97 J cm^{-2} (15 min treatment) when compared to the non-exposed control sample (P= 0.00004).
- A starting aerosol population of 6.2 × 10^5 CFU mL^{-1} was reduced to 9.1 × 10^3 CFU mL^{-1}, achieving a 1.8 log$_{10}$ reduction.
- Due to extended exposure times, natural decay of the aerosol was observed, however this was significantly less than with light treatment.

PULSED-UV RESULTS

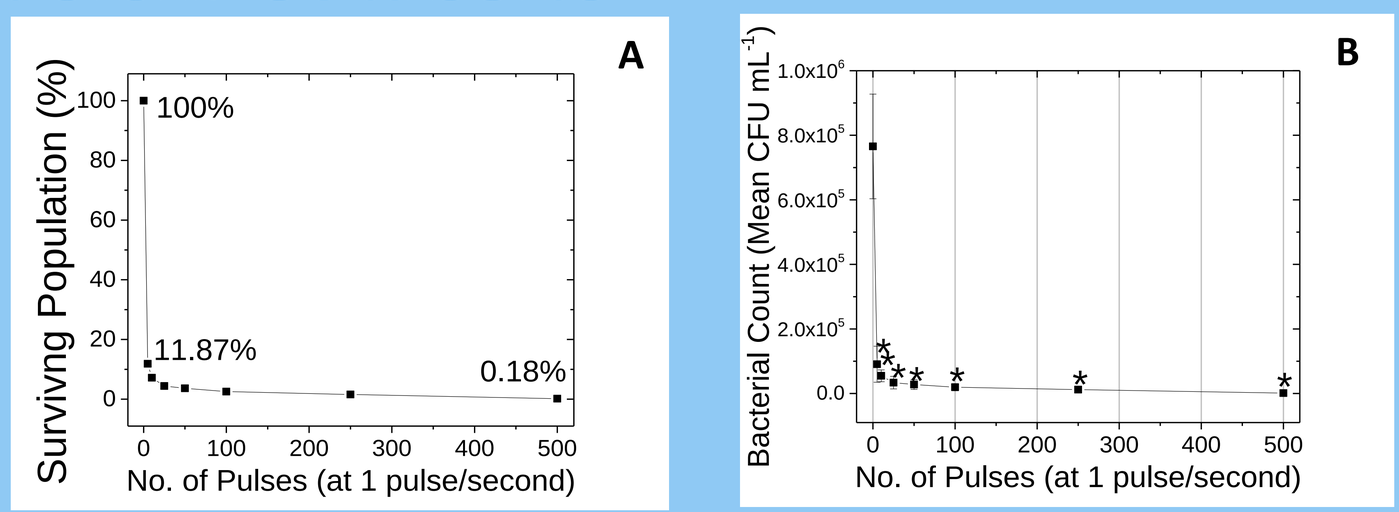

Fig 5. Investigating the susceptibility of aerosolised *S. epidermidis* to pulsed UV light. (A) Stored electrical energy was transferred from a solid state power source to a low pressure xenon flash-lamp discharging short pulses of UV light at 1 pulse/second. (B) percentage surviving (n≥9 ± SD).

- Significant reduction in airborne *S. epidermidis* was achieved after an initial dose of 5 pulses at 1 pulse/second (P=0.00000012). At this dose (5 second treatment) an 88.13% reduction was observed.
- Tailing began to be observed after 25 pulses, however the total bacterial count remaining was less than 5%.
- After 500 pulses at 1 pulse/second, a 2.8 log$_{10}$ reduction was achieved, with less than 1% of the starting population surviving at this dose (p=0.00000058).

EPSRC Engineering and Physical Sciences Research Council

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