Pulsed Ultraviolet Light Decontamination of Artificially-Generated Microbiological Aerosols

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BACKGROUND AND AIMS

- Airborne transmission of infectious organisms is a major public health concern, particularly within healthcare and communal public environments.
- Methods of environmental decontamination utilising pulsed ultraviolet light (PUV) are currently available, however it is important that germicidal efficacy against airborne contamination is established.
- This study aims to establish the susceptibility of airborne bacterial contamination to PUV and compare the germicidal efficacy to continuous-UV light (CUV) treatment.

SYSTEM METHODOLOGY

- *Staphylococcus 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 increasing durations of PUV and CUV light.
- 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 and compared.

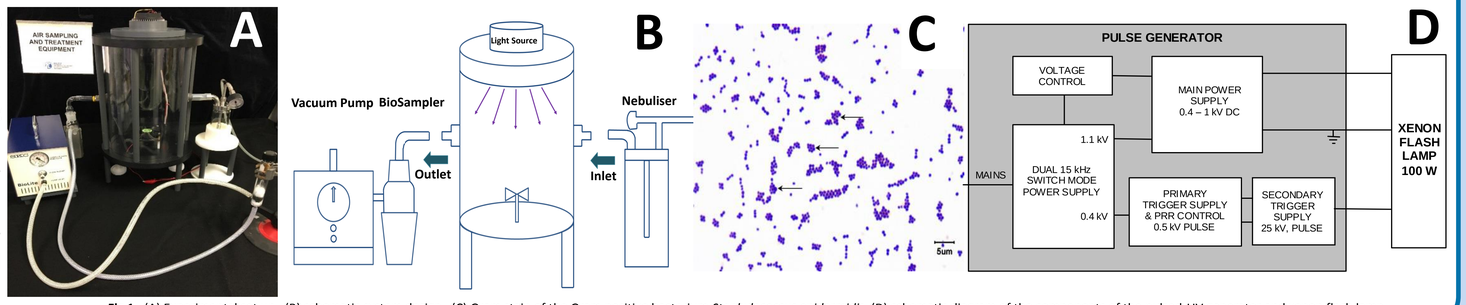

Fig 1. (A) Experimental set up, (B) schematic system design, (C) Gram stain of the Gram positive bacterium *Staphylococcus epidermidis,* (D) schematic diagram of the components of the pulsed-UV generator and xenon flash lamp.

RESULTS

Pulsed-UV

- Significant reduction (88.13%) of airborne *S. epidermidis* was achieved after 5 pulses at 1pps (P<0.001).
- Tailing was observed after 25 pulses, however the total surviving bacterial count was <5%.
- After 500 pulses at 1pps, a 2.8 $\log_{10}$ reduction was achieved, with <1% survivors at this dose (~450 μJcm^{-1}).

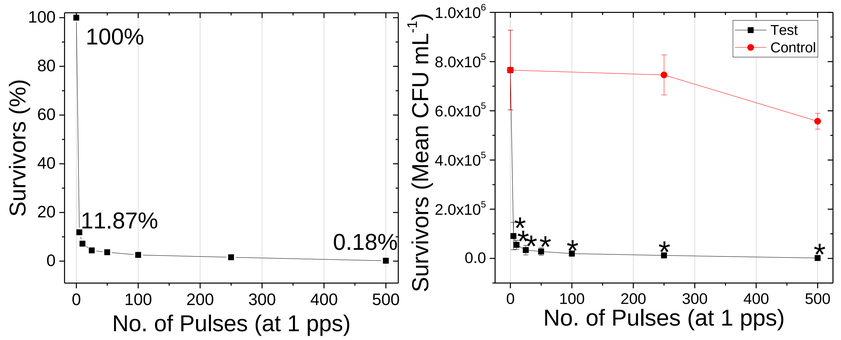

Fig 6. Susceptibility of aerosolised *S. epidermidis* to PUV-light. Optical irradiance was 900μW measured at a maximum distance of 35cm from the light source. (A) Percentage surviving data and (B) inactivation kinetics (n≥9 ± SD). * Significant inactivation (P <0.05)

Continuous-UV

- A significant (97.88%) reduction in airborne *S. epidermidis* was achieved after 5 minutes exposure.
- Tailing was also observed, however the total bacterial count remaining was <2%.
- At 60-min light treatment, a 3.2 $\log_{10}$ reduction was achieved, with <2% survivors at this dose (~730 μJcm^{-1}).

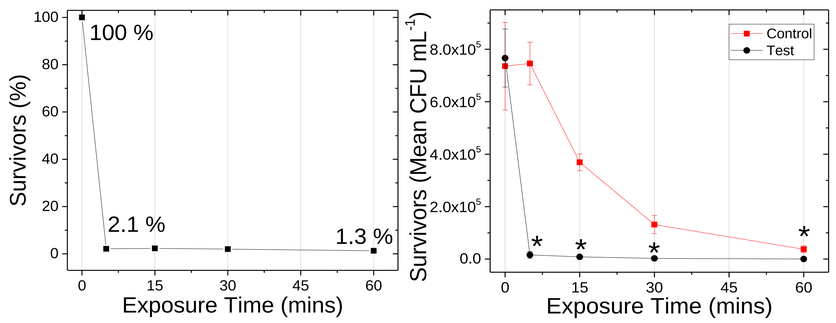

Fig 7. Susceptibility of aerosolised *S. epidermidis* to CUV-light. Optical irradiance was 203μW at a maximum distance from the light source. (A) percentage surviving data and (B) Inactivation kinetics (n≥9 ± SD). * Significant inactivation (P <0.05)

LIGHT SOURCES

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 1pps and pulse energy of 20 J.

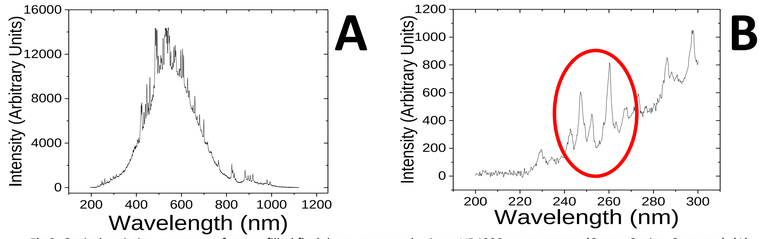

Fig 2. Optical emission spectrum of xenon filled flash lamp measured using a HR4000 spectrometer (Ocean Optics, Germany). (A) Original spectrum of broadband light and (B) UV rich region.

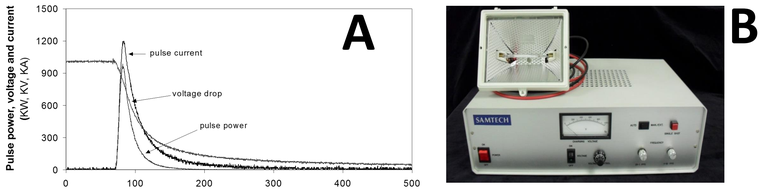

Fig 3. (A) Waveforms of the Xenon-filled flash lamp, recorded at an operating voltage of 1 kV and (B) xenon flash lamp and pulsed power generator.

Continuous-UV Light: Germicidal PLS 9W 2 pin G23 bulb emitting short wave radiation with a peak at 253.4 nm.

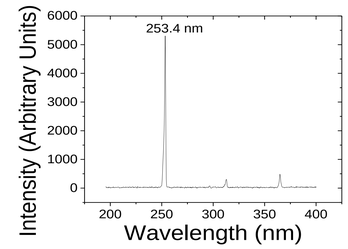

Fig 4. Optical emission spectrum of continuous-UV light bulb with peak output at 253.4 nm.

Fig 5. Germicidal CUV light bulb (EasyBulbs, UK).

CONCLUSIONS

- PUV-light was much more efficient for decontamination of airborne bacteria due to its delivery of very high peak power over a shorter period of time (20μs) compared to the lower energy output of CUV light (500 seconds versus 3600 seconds, respectively).
- Safety restrictions of UV light limit its application to unoccupied environments or sealed enclosures, however, reduced treatment times of PUV-light provides operational advantages over CUV-light treatment.

EPSRC Engineering and Physical Sciences Research Council

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