Comparison of the Antimicrobial Efficacy and Germicidal Efficiency of 405-nm Light for Surface Decontamination

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INTRODUCTION

The persistence of nosocomial bacteria on hospital surfaces provides a significant source of infection transmission within the clinical environment[1].

Although traditional cleaning procedures are essential to minimise pathogen spread, an estimated 50% of 'high-touch' surfaces are commonly missed using these techniques[2].

Violet-blue 405-nm light demonstrates broad antimicrobial properties[3] at exposure levels safe for mammalian cells[4].

Low-irradiance 405-nm light has recently been developed as a method of 'whole-room' decontamination within occupied environments, with studies demonstrating successful reductions of environmental bacteria in wards and operating theatres[5,6].

This study aims to investigate the antimicrobial efficacy of 405-nm light for the decontamination of surfaces and how the dose-response kinetics are affected by use of differing light irradiances.

METHODS

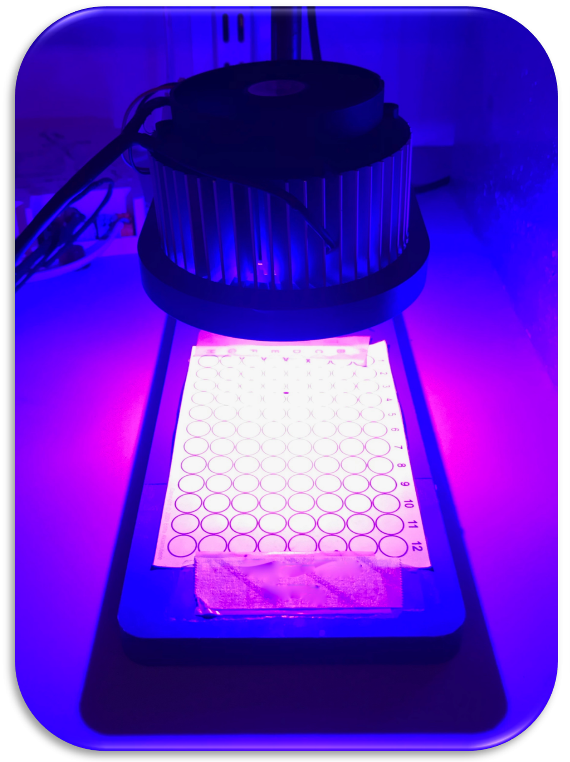

Fig. 1. 405-nm LED array for exposure of bacterial samples to 5 and 50 mWcm^{-2} irradiances.

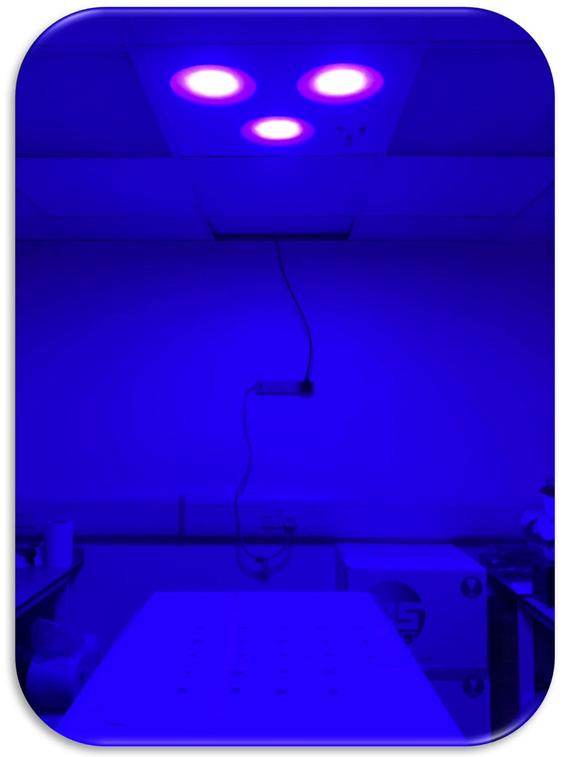

Fig. 2. Low irradiance 405nm light system used for exposure of bacterial samples to 0.5 mWcm^{-2} irradiances.

- *Staphylococcus aureus* and *Pseudomonas aeruginosa* were selected as model Gram-positive and Gram-negative species for use in experiments.
- Surface-seeded bacteria were exposed to increasing doses of 405-nm light at three discrete irradiances (0.5, 5 and 50 mWcm^{-2}; **Table 1**).
- An ENFIS Innovate UNO 24 LED array (**Fig. 1**) was used for exposures at 5 and 50 mWcm^{-2} and a 405nm light prototype environmental decontamination system (**Fig. 2**) was used for exposures at 0.5 mWcm^{-2}.
- Post-exposure, inactivation kinetics at each respective irradiance were established and bacterial susceptibility at equivalent light doses compared.

Table 1. 405-nm light treatment regimes for *S. aureus* and *P. aeruginosa;*

[Dose (Jcm^{-2}) = Irradiance (mWcm^{-2}) x Exposure Time (s)].

Irradiance (mWcm^{-2})	0.5	5	50	Dose Delivered (Jcm^{-2})
Exposure Time (minutes)	100	10	1	**3**
	200	20	2	**6**
	300	30	3	**9**
	400	40	4	**12**
	500	50	5	**15**
	1000	100	10	**30**
	1500	150	15	**45**
	2000	200	20	**60**
	2500	250	25	**75**
	3000	300	30	**90**

RESULTS

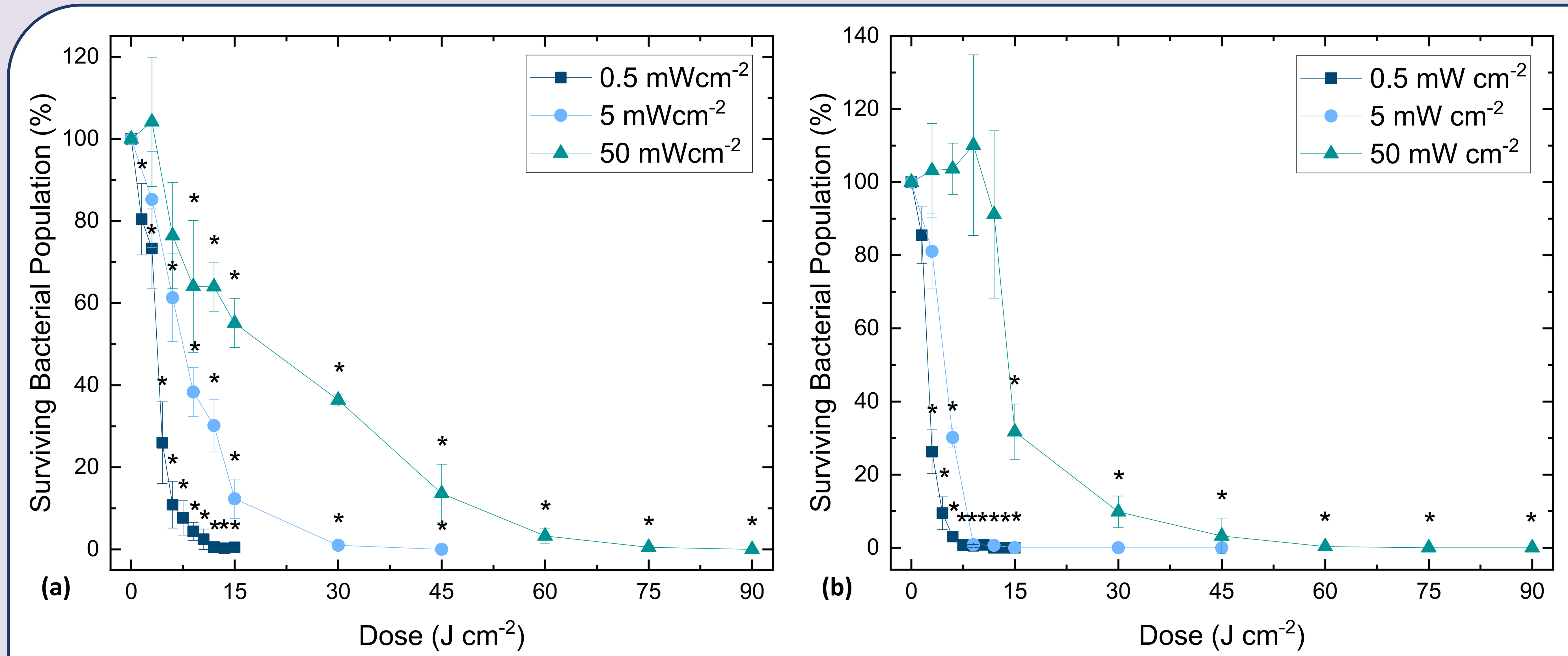

Fig. 3. Comparison of the inactivation kinetics of surface-seeded (a) *Staphylococcus aureus* and (b) *Pseudomonas aeruginosa* upon exposure to 405-nm light at irradiances of 0.5, 5 and 50 mWcm^{-2} (n ≥ 3 ± SD). Asterisks (*) represent a significant reduction in bacterial populations in comparison to non-exposed controls (P ≤ 0.05).

- Exposure at 0.5 mWcm^{-2}: 3 Jcm^{-2} was required to achieve significant reductions in both species compared to non-exposed controls (P ≤ 0.05).
- Exposure at 5 mWcm^{-2}: **double the energy** (6 Jcm^{-2}) was required for both species to achieve similar significant reductions
- Exposure at 50 mWcm^{-2}: greater doses of **9** and **15 Jcm^{-2}** were required for equivalent reductions of *S. aureus* and *P. aeruginosa*, respectively.
- For both species, **3-5 times less dose** was required to achieve significant reductions when exposed at the **lowest irradiance** (0.5 mWcm^{-2}) in comparison to the highest irradiance (50 mWcm^{-2}).

CONCLUSIONS

- Surface-seeded nosocomial bacteria, *S. aureus* and *P. aeruginosa*, were successfully inactivated by 405-nm light at the range of irradiances used.
- The germicidal efficiency of 405-nm light was significantly enhanced when a lower irradiance (~ 0.5 mWcm^{-2}) was utilised.
- Coupled with the increased safety benefits of 405-nm light compared to UV light, these findings support the use of low-irradiance 405-nm light for continuous decontamination applications within occupied healthcare environments.
- Results highlight that the mode of application can have a significant impact on the efficacy of microbial inactivation, therefore further investigation is required into the associated photo-chemical inactivation mechanisms, as this will be crucial for optimisation of the technology for a range of infection control applications.

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