Efficacy of a Low Irradiance Antimicrobial 405-nm Visible Light System for Inactivation of Bacteriophage Phi6 as a Surrogate for SARS-CoV-2

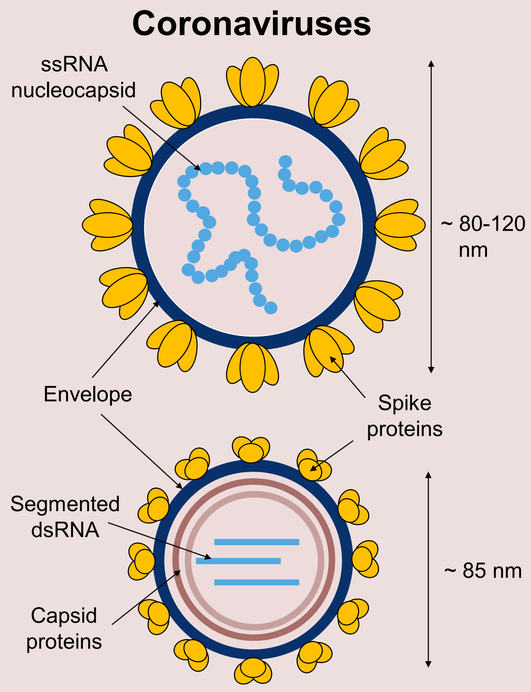
Lucy G Sinclair[1*], Zornitsa Ilieva[2], Scott J MacGregor[1] and Michelle Maclean[1,2]

[1]The Robertson Trust Laboratory for Electronic Sterilisation Technologies (ROLEST), Department of Electronic & Electrical Engineering, University of Strathclyde, Glasgow, UK.
[2]Department of Biomedical Engineering, University of Strathclyde, Glasgow, UK.
*Contact email: lucy.g.sinclair@strath.ac.uk

University of Strathclyde Engineering
UKRI Engineering and Physical Sciences Research Council

INTRODUCTION

- The COVID-19 pandemic has increased the necessity for novel strategies to safely decontaminate public areas.
- Low irradiance 405-nm light environmental decontamination systems (EDS) have recently been developed, with studies demonstrating their ability to safely reduce bacterial levels within occupied healthcare environments[1-5].
- The 405-nm light emitted from these systems induces the excitation of photosensitive molecules, namely porphyrins, within microbial cells, initiating the production of reactive oxygen species and ultimately cell death[6,7].
- Due to the absence of porphyrin molecules from viral structures, the viricidal properties of this technology are less understood.



This study investigates the efficacy of low irradiance 405-nm light systems for the inactivation of bacteriophage phi6 as a surrogate for SARS-CoV-2.

METHODS

- A ceiling-mounted 405-nm light EDS in 'blue-only' mode (**Fig. 1A**) was used to expose phage samples.
- Bacteriophage phi6 was suspended in SM buffer and artificial human saliva at low (~10^3 PFU mL^{-1}) and high (~10^7 PFU mL^{-1}) densities, and 3 mL volumes were light-exposed at ~1.5 m below the light source (**Fig. 1B**).
- At this distance, the irradiance provided was ~0.5 mW cm^{-2}, which is representative of the irradiance levels which can illuminate high-touch surfaces within clinical areas (e.g., bed rails, tray table, bedside table, IV poles).
- Post-exposure, the surviving phage population was determined using a double agar overlay plaque assay, overnight incubation and subsequent enumeration.

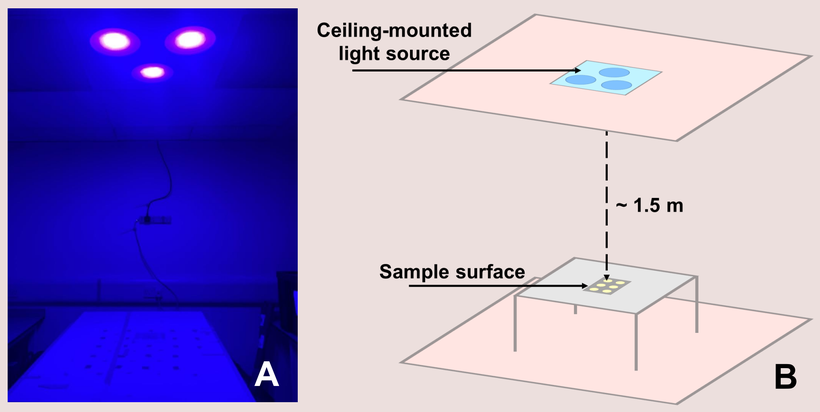


Fig. 1. Experimental set-up (A) photographed and (B) modelled.

RESULTS

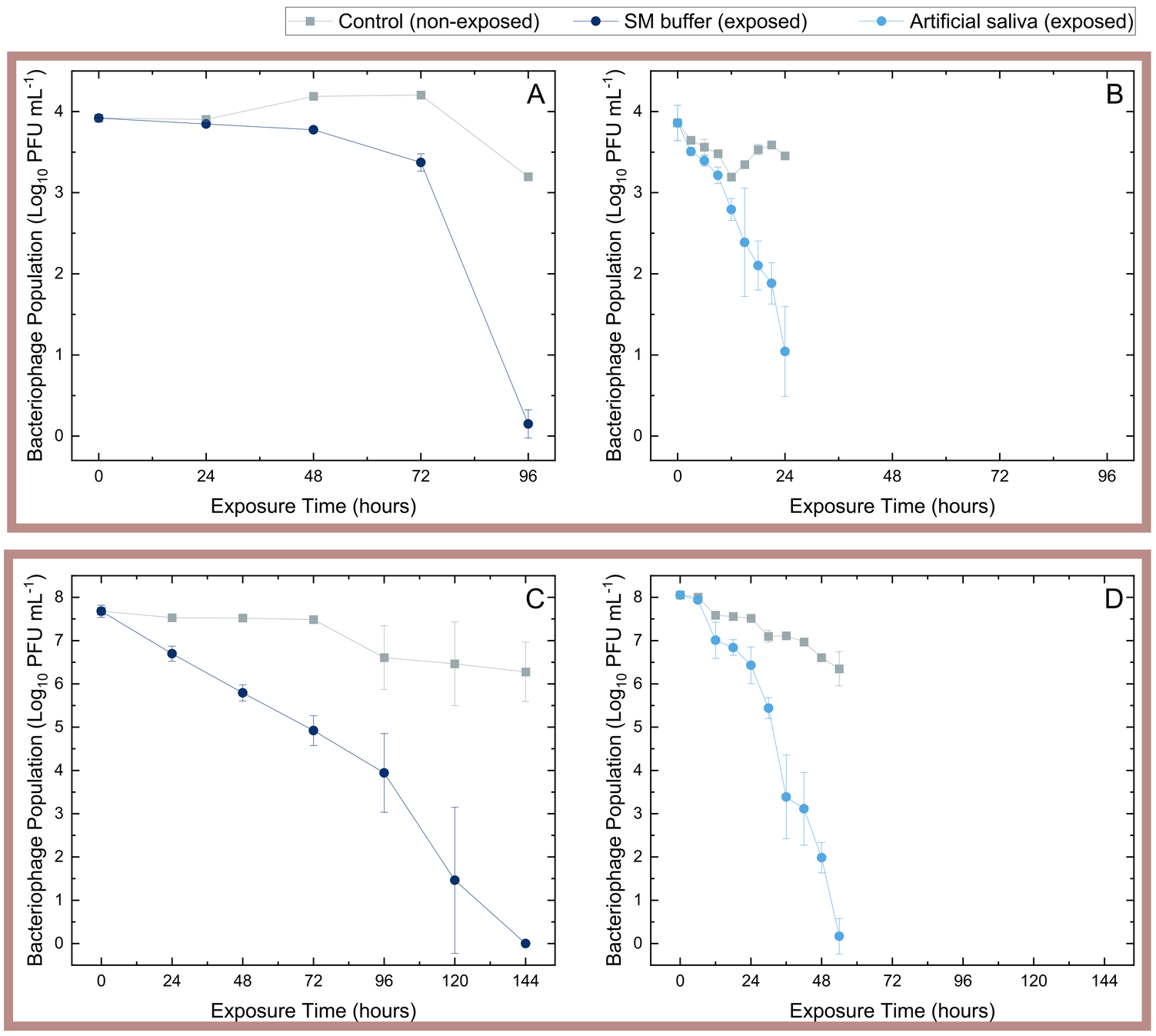


Fig. 2. Inactivation of bacteriophage phi6 suspended at 10^{3-4} PFU mL^{-1} in (A) SM buffer and (B) artificial saliva, and at 10^{7-8} PFU mL^{-1} in (C) SM buffer and (D) artificial saliva, upon exposure to increasing doses of ~ 0.5 mWcm^{-2} 405-nm light (n ≥ 4 ± SD).

Table 1. Comparison of mean percentage phage reductions when exposed at low and high seeding densities in SM buffer and artificial saliva. Asterisks (*) represents a significant reduction in comparison to non-exposed controls (P ≤ 0.05).

Exposure Time (hours)	Mean Percentage Phage Reduction (%)			
	SM buffer 10^3 PFU mL^{-1}	SM buffer 10^7 PFU mL^{-1}	Artificial saliva 10^3 PFU mL^{-1}	Artificial saliva 10^7 PFU mL^{-1}
6			31.36*	12.12
12			58.63*	61.87*
18			95.60*	78.95*
24	12.19*	84.04*	**99.41***	87.69*
36				**99.94***
48	60.48*	97.97*		99.99*
72	83.06*	99.64*		
96	**99.32***	98.98*		
120		**99.89***		

- Low-irradiance 405-nm light **significantly reduced** (P ≤ 0.05) phi6 suspended in both artificial saliva and SM buffer at both low and high seeding densities.
- Inactivation was significantly enhanced (P ≤ 0.05) when exposed in artificial saliva: **83.3-87.5%** and **50% less dose** was required for a 1-log_{10} reduction of phi6 at low and high seeding densities, respectively.
- Significantly greater exposure times were required for complete/near-complete inactivation at higher densities (P ≤ 0.05); however, the dose requirements for a 1-log_{10} reduction were **similar** for both low and high seeding densities.

CONCLUSIONS

- Low-irradiance 405-nm light systems can successfully reduce phi6 at irradiances typically implemented for whole-room decontamination.
- Inactivation was successfully achieved in SM buffer; suggesting 405-nm light viral inactivation is possible in the absence of external photosensitisers, possibly due to light interactions with the phage envelope[8].
- An increased inactivation efficacy was observed when exposed in saliva, suggesting photosensitive components within this suspension can act as external photosensitisers and impart localised oxidative damage to the phage; highlighting its potential for decontamination of SARS-CoV-2 in environmental respiratory droplets.
- These findings establish a basis for further investigation into the viricidal properties of 405-nm light and demonstrate that, with further investigation, low irradiance 405-nm light systems hold potential as a novel approach to tackling COVID-19 transmission within occupied settings.

References

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Acknowledgements

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