Efficacy of Inactivation of *Pseudomonas aeruginosa* by Multiple-Wavelength UV LEDs

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BACKGROUND

Ultra violet (UV) light technology has been widely adapted as a method of water treatment that does not result in the formation of carcinogenic disinfection by-products (DBPs). The emerging UV technology of light emitting diodes (LEDs) is mercury-free and moreover has enormous potential for point-of-use (POU) water disinfection since they are much smaller, lighter, and less fragile.

While extensive studies have been conducted on microorganism inactivation using germicidal UV LEDs targeting microbial indicators, limited studies have been focused on waterborne pathogens (Beck et al., 2017; Rattanakul and Oguma, 2018; Woo et al., 2018).

RESEARCH OBJECTIVE

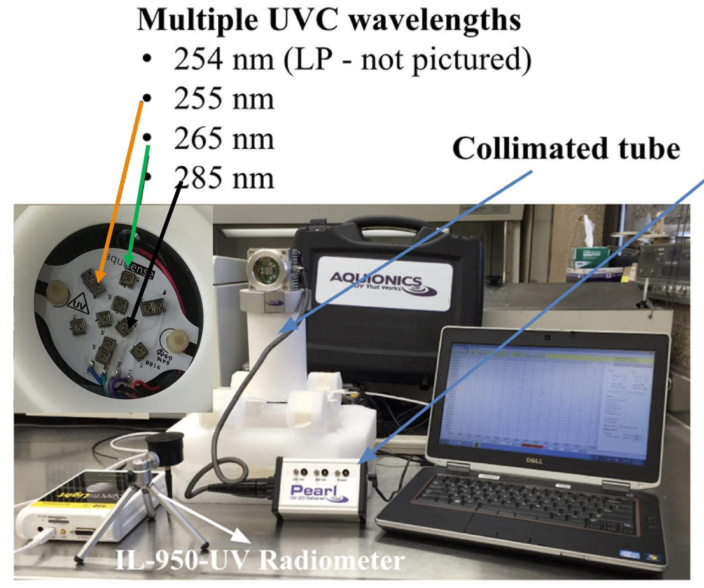
In this study, we investigated a range of UV wavelengths to formulate an efficient water treatment strategy for *Pseudomonas aeruginosa* and explored the synergistic effect of UV reflective materials and strategic sequential exposure to multiple wavelengths of UV light.

METHODS AND MATERIALS

Log phase *P. aeruginosa* cells were prepared by overnight culture at 35°C for 24 h in nutrient broth. The cells were then washed 3 times with Butterfield's buffer, and a sample with a concentration of 1.0 E+5 colony forming units (CFU)/mL was created.Bench-scale inactivation tests were carried out using the Collimated Beam apparatus with germicidal wavelength pictured below.A monochromatic low-pressure (LP) UV lamp emitting at 254 nm was tested for comparison.

UV-LED Collimated Beam Test

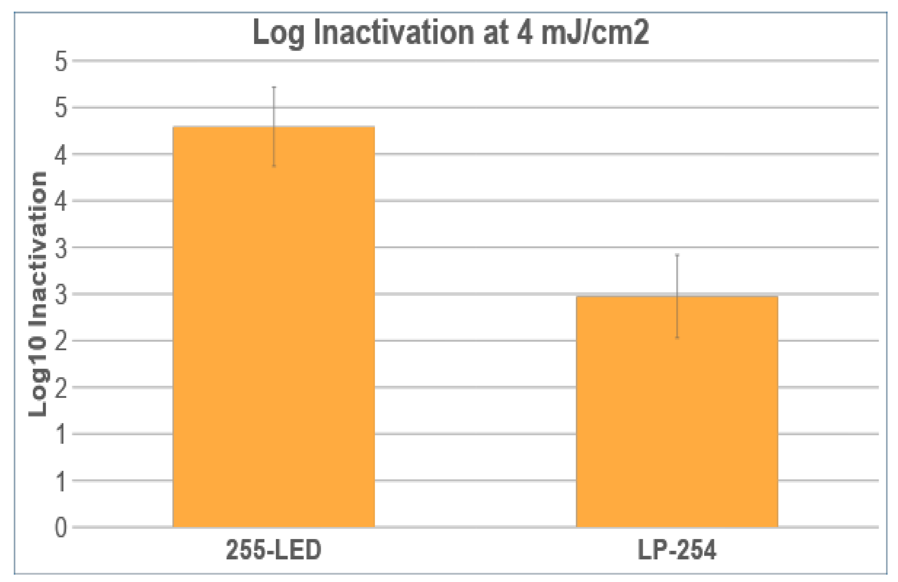
Multiple UVC wavelengths
- 254 nm (LP - not pictured)
- 255 nm
- 265 nm
- 285 nm

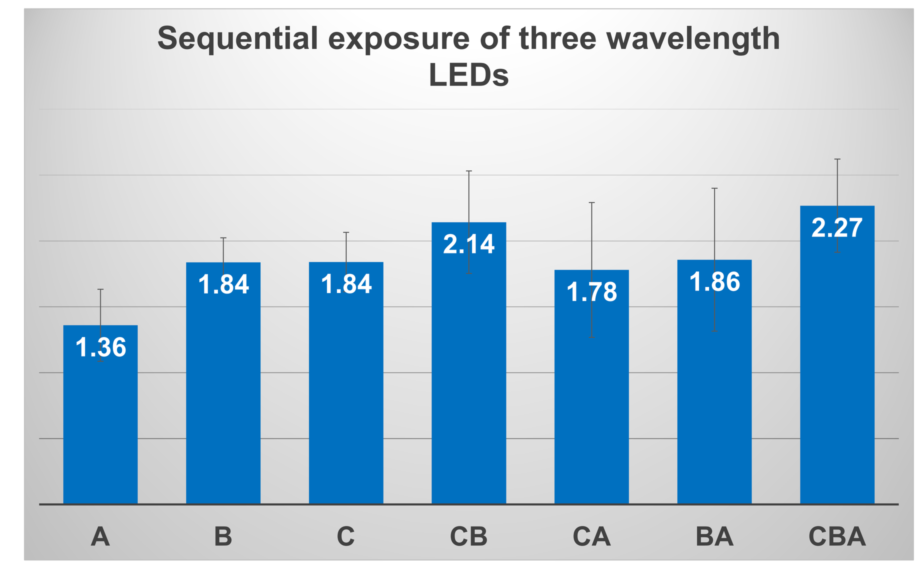


$$L = -\log_{10}\left(\frac{N_d}{N_0}\right) = k(U_d)$$

- L: Log inactivation of viruses by UV disinfection
- N_0: Initial concentration of bacteria
- N_d: Concentration of bacteria after UV radiation
- k: Inactivation rate constant
- U_d: the calculated UV doses

RESULTS AND DISCUSSION

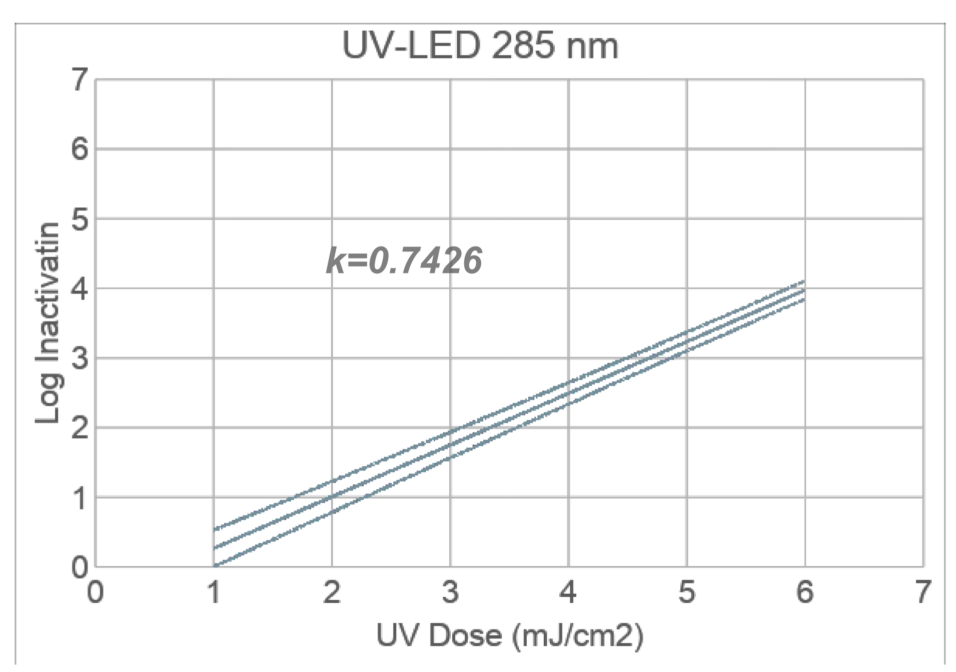


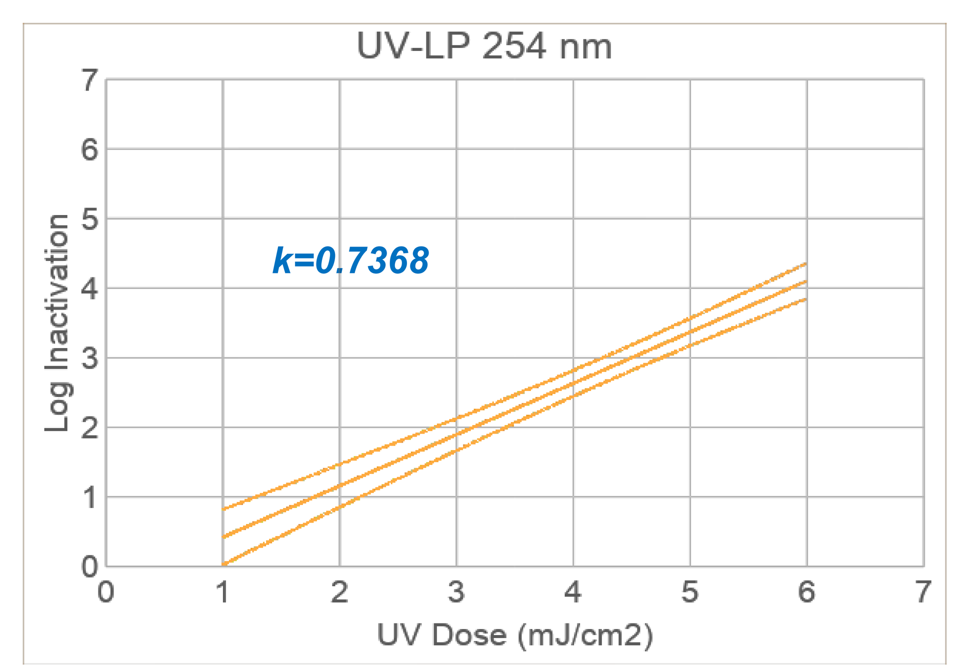


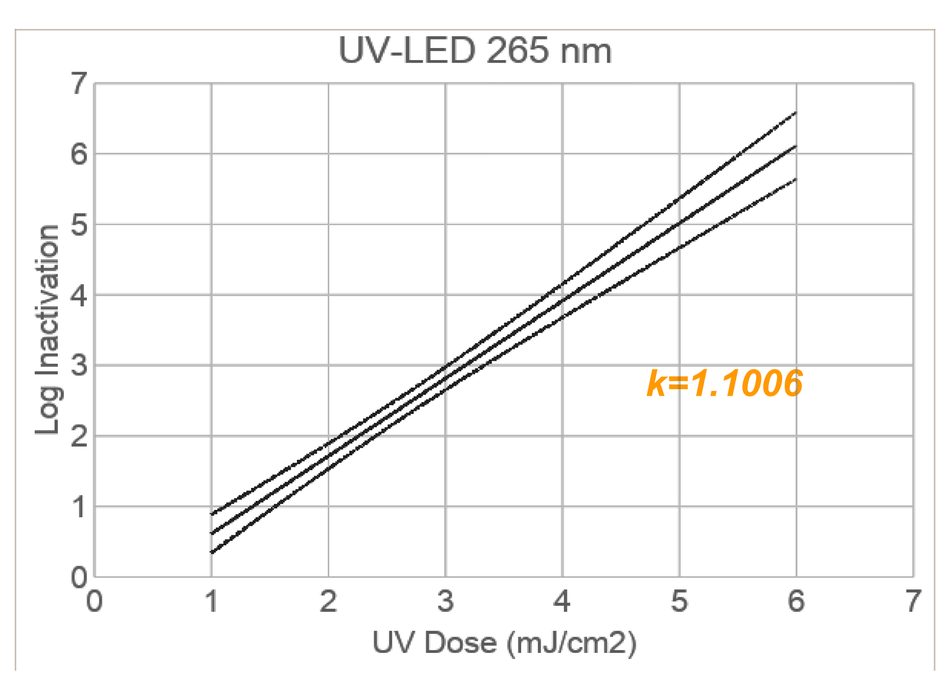
A: 255 nm, B: 265 nm, C: 285 nm

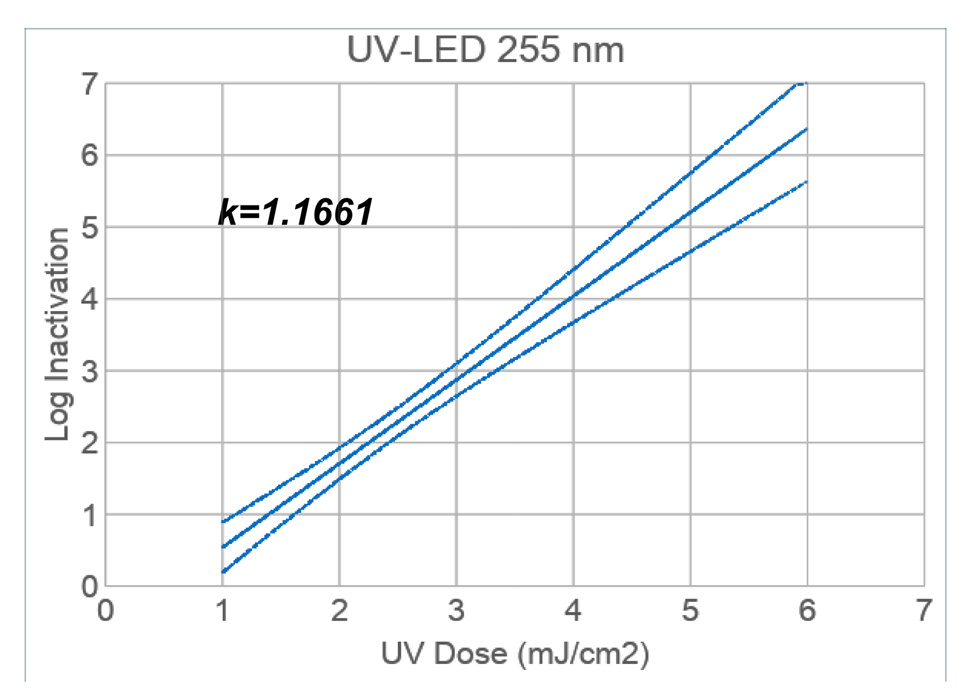
- Overall log-inactivation efficacy: 265nm ≈ 255nm > 285nm ≈LP
- 4 log inactivation: 255nm @4.0 mJ/cm², LP @5.8 mJ/cm² (48% increase)
- Evidence of synergistic effect: Sequential exposure of three wavelengths resulted in approximately 0.4 log higher inactivation credit
- Reflective samples demonstrate higher efficacy than non-reflective counterparts.
- Overall, LED is more effective and requires less exposure than LP.Ideal for POU application.

WHICH WAVELENGTH IS BEST?









SUMMARY

❖*P. aeruginosa* (a gram-negative, opportunistic premise plumbing pathogenic bacteria) was exposed to different dosages of UV radiation.

❖Log10 inactivation of *P. aeruginosa* was calculated, and inactivation rate constants were estimated using linear least squares regression.

❖The LED emitting at 265 nm and 255 nm demonstrated relatively high inactivation of *P. aeruginosa*, followed by 285 nm and LP UV at 254 nm.

❖Greater log inactivation of multiple wavelength exposures when compared to single wavelength exposures of the same UV dose.

❖Reflective coatings at the bottoms of petri dishes showed a significant improvement in inactivation rates.

LEDs are not only more energy efficient than LP UV lamps, but they also lower the exposure time dramatically. UV LEDs demonstrated the capability to effectively inactivate *P. aeruginosa.* 265 nm and 255 nm wavelengths of the LEDs tested greatly outperformed conventional LP UV lamps. Furthermore, the synergistic effects of sequential exposures and the use of UV reflective aluminum foil encourages further studies on its applicability for sustainable water treatment and the development of a low power UV-LED POU device.

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