Atmospheric Simulation Chamber: The Synergistic Effects of UV Irradiation and Hydrogen Peroxide on Disinfecting Airborne Viruses

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This study presents a comprehensive analysis of airborne virus deactivation techniques, employing advanced disinfection methods in a controlled 19 m³ atmospheric simulation chamber. The research focuses on the synergistic effects of ultraviolet (UV) irradiation (UVA and UVC wavelengths) and hydrogen peroxide (H_2O_2) in neutralizing aerosolized viruses, with an emphasis on creating conditions closely mimicking typical indoor air environments. By utilizing bacteriophage T4 aerosolized in a pig mucin medium, the study simulates human respiratory emissions, providing a realistic surrogate for pathogenic virus-laden aerosol particles.

For this study, an experimental setup was designed and fabricated to simulate the generation of particles comparable in size to those produced by human breathing. The experimental setup employed an aerosol generator that operated based on the saturator/condenser mechanisms. Through this system, by condensation water vapor, the original size of the particle (120 nm) increased to 550 nm, forming a complex structure consisting of the virus and a mucin solution enveloping it.

Key findings demonstrate the potent, dose-dependent virus inactivation capabilities of UVC irradiation, achieving 90%, 99.8%, 99.9% virus DNA destruction at UVC dosages of 7, 8.93, and 17.83 $mJ.cm^{-2}$, respectively, of the initial viral load. Besides, by comparing our results with previous study and also use DI water as a carrier medium, it was found that presence of mucin in carrier medium reduces the UVC disinfection ability.

The study further explores UVA irradiation's contributory role in decreasing virus viability, particularly at higher doses, underlining its potential as an auxiliary disinfection method. Our results showed that UVA, at a dose of 135.5 $J.cm^{-2}$, resulted in an 80% viral load decreasing for the T4 bacteriophage.

Additionally, the effectiveness of H_2O_2, both in the absence and presence of UV light, reveals its potent antiviral properties, significantly enhancing viral DNA destruction. The present study reveals that even low concentrations of hydrogen peroxide (<1 ppm) can significantly destruct airborne viruses, with effectiveness increasing as the concentration rises. For example, at just 32 ppb, we observed a 78% of DNA molecules were destructed compare to initial condition, which increased to 97% at 316 ppb, even under dark conditions. Our results demonstrated that for the UVA with the doses of 135.5 $J.cm^{-2}$ and UVC with the doses of 6.7 $mJ.cm^{-2}$, over 99.999 of the initial loaded virus DNA was destructed. The results are presented in Fig. 1.

The integration of UVA or UVC irradiation with hydrogen peroxide in the gas phase represents a promising advancement in air disinfection technology, with significant implications for public health and indoor air quality management.

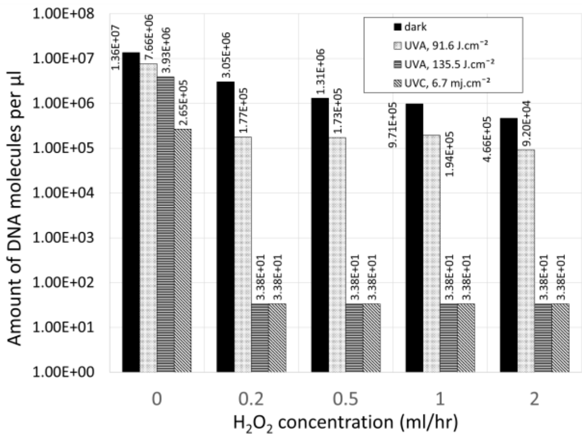

Figure 1. The effect of H_2O_2 on the detected DNA of Bacteriophage T4 for different UV light sources.

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