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Bioaerosol Inactivation in Various Air Ionization Stages of an Air Cleaning Device

Objective: To investigate the performance of bioaerosol inactivation/capture in non-thermal plasma (NTP), UV-C photolysis, bipolar ionization (BI), and electrostatic precipitation (ESP) stages of multistage air cleaner, across varying airflow rates of individual and combined stages.

Methods: The prototype air cleaning device operated sequentially through NTP, UV-C, BI, and ESP stages. Aerosolized bacterial cultures of Lactobacillus casei and Escherichia coli were introduced into the system before active stages, and samples were collected using impingers filled with physiological solution. Bacterial inactivation efficiency was determined by counting viable colonies post-incubation. Energy consumption and ozone emissions were monitored to evaluate the system's operational safety. Performance metrics were assessed at airflow rates ranging from 50 to 600 m^3/h.

Results: The multi-stage device achieved over 99% inactivation efficiency for both bacterial strains at the lowest airflow rate (50 m^3/h). Efficiency declined with increasing airflow rates but remained above 94% at the highest flow rate (600 m^3/h). Among individual stages, the NTP process demonstrated the highest standalone inactivation efficiency, followed by UV-C photolysis and BI. The integration of all stages significantly enhanced performance, achieving synergistic effects that improved overall disinfection efficacy. Despite the generation of ozone in the NTP and BI stages, the system's ozone destruction unit effectively reduced emissions to safe levels while operating at 99.6 % efficacy at 200 m3/h, meeting health standards.

Conclusion: The results demonstrate that the multi-stage air-cleaning system is highly effective in inactivating bioaerosols, providing a promising solution for improving indoor air quality in healthcare, residential, and commercial environments. Its ability to maintain ozone levels within safety limits, combined with its high disinfection efficiency, highlights its potential for widespread application. Further optimization of the system to enhance performance at higher airflow rates and minimize ozone emissions could increase its practical utility in real-world settings.

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