Evaluating Indoor Air Quality Impacts of Far-UVC (222 nm) in a Controlled Full-Scale Office Environment with Human Subjects

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SUMMARY
Far-UVC (222 nm) irradiation effectively inactivates airborne pathogens, but photolyzes oxygen to generate ozone, potentially initiating indoor chemistry that may form secondary pollutants. To evaluate these impacts in a realistic setting, we conducted experiments in a full-scale (158 m^3) office chamber. The study involved 13 sessions with human subjects (n=4–8) under typical mechanical ventilation (0.7–0.8 h^{-1}). We monitored ozone, ultrafine particles, and nitrogen oxides, and took time-integrated volatile organic compounds (VOCs) samples before and after the lamps on. We found that while far-UVC operation increased ozone concentrations, the elevation in the occupied room was modest (median increase 1.44 ppb). We didn't observe discernible secondary aerosol and VOCs formation. Participant surveys indicated that air quality remained acceptable throughout the experiments. These results suggest that in ventilated, occupied offices, far-UVC can be deployed with minimal impact on chemical indoor air quality.

KEYWORDS
Germicidal Ultraviolet Disinfection; Ozone; Secondary Organic Aerosols; Indoor Chemistry; Exposure

1 INTRODUCTION
Air disinfection with far-UVC light (222 nm) from filtered KrCl excimer lamps is a promising intervention against infectious aerosols. Unlike conventional 254 nm germicidal UV, far-UVC poses minimal risk to skin and eyes, allowing for continuous operation in occupied spaces. However, 222 nm radiation photolyzes molecular oxygen to form ozone (O_3), a respiratory irritant and precursor to secondary indoor pollutants. Ozone reacts with alkenes (e.g., terpenes from cleaning products) and skin oils (squalene) to produce secondary organic aerosols (SOA) and volatile oxidation. Previous studies on far-UVC chemistry have largely been confined to small chambers or unoccupied spaces with high specific VOC sources. There is a critical lack of data characterizing pollutant dynamics in realistic, full-scale environments.

2 METHODS
Experiments were conducted in the FLEXLAB facility at LBNL, a configurable 158 m^3 environmental chamber furnished as an open-plan office with six workstations and dividers. Mechanical ventilation provided outdoor air supply with a mean air change rate of 0.77 h^{-1}. Four commercial filtered KrCl far-UVC luminaires (Far UV Technologies) were installed on the ceiling. The mean fluence rate in the occupied zone was measured at 0.77 µW cm^{-2} (at 1.37 m height), well within ACGIH threshold limit values (TLV). We recruited participants for 13 separate sessions simulating typical office work. Each session lasted approximately 3 hours, consisting of a baseline period (lamps off) followed by an exposure period (lamps on). Real-time instrumentation included three ozone monitors (2B Technologies) and three Condensation Particle Counter (CPC, Aerosol Dynamics Inc.) measuring at different locations. For each session, we collected time-integrated VOCs and aldehydes using sorbent

tubes and DNPH cartridges at three specific time windows: pre-activation of the lamps (15–60 min), early activation (75–120 min), and late activation (135–180 min).

3 RESULTS AND DISCUSSION

Figure 1 shows time-series data collected in a typical day of experiment, which includes human subject experiments in the morning and afternoon and lamp cycles in the early morning and night, with the room unoccupied.

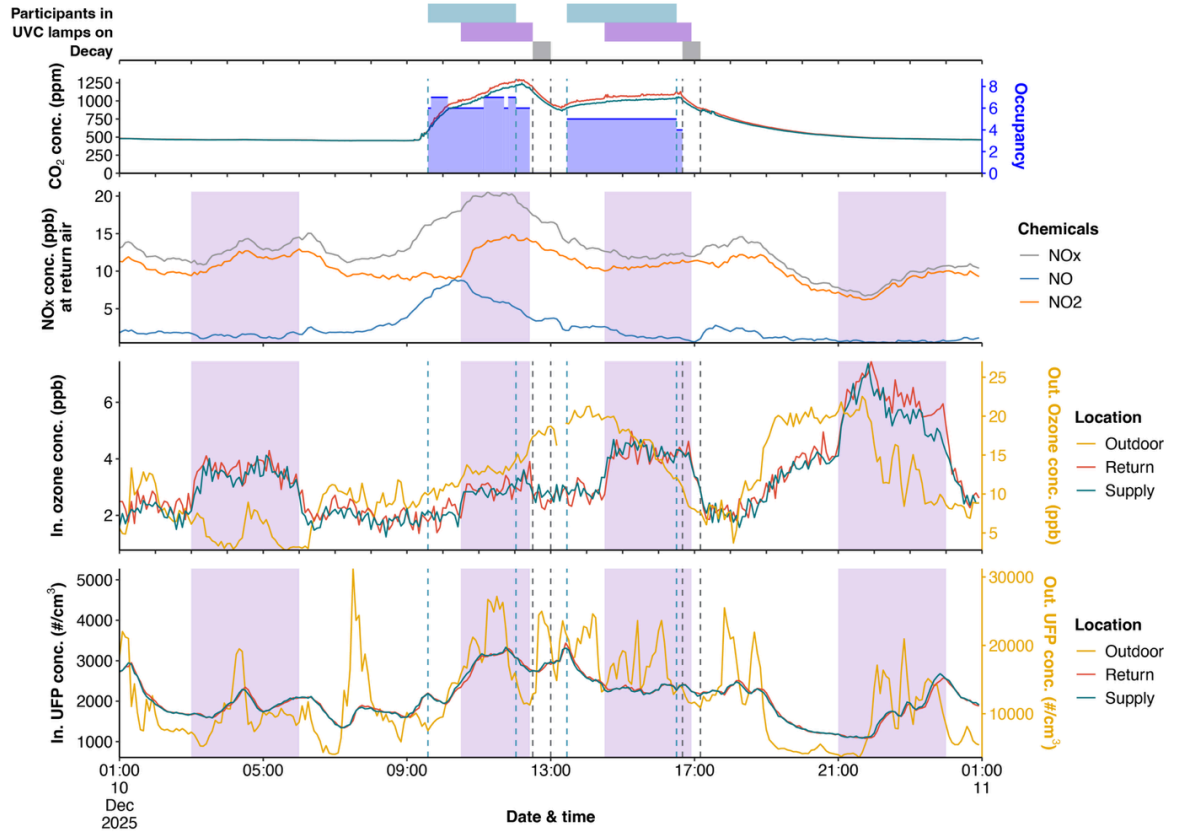

Figure 1. Concentrations of CO_2, Ozone and UFP measured at different locations in the chamber during a typical day of experiments. NO_X were only measured at return air.

In the occupied office, the median ozone increase during far-UVC operation was 1.4 ppb (IQR: 0.8-1.8 ppb). During unoccupied periods, the ozone increase was somewhat higher, up to~4 ppb. Reactions with nitric oxide from outdoor air reduced the residual ozone, sometimes to <1 ppb. We observed no discernible formation of UFP or VOCs attributable to lamp operation. This contrasts with previous studies in high-terpene environments (e.g., restrooms with air fresheners) and suggests that in typical offices with standard ventilation and moderate VOC load, the ozone produced by far-UVC does not lead to harmful product formation.

5 CONCLUSIONS

This full-scale study demonstrates that deploying Far-UVC at germicidal intensities in a ventilated, occupied office leads to only minimal changes in indoor air quality, with no pollutants rising to harmful levels.

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