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# Mitigating airborne pathogen transmission in indoor environments: Inactivation effects of environmental factors

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**Objective**: Urbanization and rising energy demand in buildings challenge public health by increasing airborne disease transmission risks in crowded indoor spaces. While improved ventilation has been recommended during the COVID-19 pandemic to lower infection risks, it also raises energy consumption, creating a trade-off between energy use and health protection. Current strategies like ventilation and portable air cleaners (PACs) are used to reduce indoor pathogens. However, factors like relative humidity (RH) and air composition have been studied in less detail, and they significantly affect pathogen inactivation by altering aerosol salinity and pH, to which pathogens are sensitive. Despite extensive biological research on the inactivation in droplets, their integration into indoor air studies remains limited. This study explores pathogen inactivation and removal through experiments examining how RH, air composition –particularly volatile ammonia, ventilation rates, and PACs impact pathogen survival. This abstract focuses on the inactivation effects of RH and air composition to develop sustainable infection control strategies.

**Methods**: In a biosafety level 1 chamber, experiments used *E. coli* as a surrogate for respiratory pathogens. Artificial saliva (AS) was aerosolized using a coughing machine to simulate respiratory emissions with 10 coughs per series. A factorial design was employed to study pathogen inactivation across three RH levels (30%, 50%, 70%) and distances (1m, 2m, 4m). Air temperature and air change rate were fixed at 23℃ and 1, respectively. Subsequent experiments will assess the effect of ammonia concentrations (3.65 ppb, 36.5 ppb, 365 ppb) on pathogen inactivation. Additional surrogates such as *Staphylococcus epidermidis*, Φ6, and MS2 will also be included. Pathogen removal experiments will vary ventilation rates, PAC placements (near the source, midway in the cough jet, and at certain distances), and source distances. Bioaerosol sampling occurred immediately after emission and after a decay period, using 6-stage Andersen impactors. GRIMM 11-D aerosol spectrometers and MetOne HHPC+ optical particle counters continuously monitored size-resolved particle concentrations at the center of the cough jet, positioned at designated distances from the source. Particle concentrations at three locations, 1 m from the bioaerosol sampling point and outside the cough jet, were measured using Graywolf PC-3500 optical particle counters. Environmental parameters such as chamber relative humidity, $CO_2$, and ammonia levels were continuously recorded by an Onset HOBO Max $CO_2$ logger and a Picarro $NH_3$ analyzer, at locations unaffected by the cough jet.

**Results**: Over 90% of particles were below 2 μm, with only AS being expelled. When *E. coli* was present, 85% of the particles remained in that same size range. Adding *E. coli* reduced particle concentrations compared to pure AS due to viscosity changes. Coughing caused particle concentrations in the jet to spike, but they quickly decreased, indicating significant immediate exposure to pathogen-laden particles during coughing. In pathogen inactivation experiments, RH could affect pathogen survival by altering aerosol particle salinity and size. At low RH, particle evaporation accelerated, shifting size distribution toward smaller particles. Mid-range RH would promote supersaturation, enhancing pathogen inactivation, while salt efflorescence hinders further inactivation at low RH. As for volatile ammonia, high ammonia levels are expected to raise aerosol pH indoors, reducing acidity and potentially slowing inactivation. Unlike RH, ammonia does not directly affect particle sizes. As distance from the coughing machine increases, exposure to pathogen-laden aerosols decreases as the cough jet dissipates, becoming more susceptible to airflow disruption. This study emphasizes the distinct effects of RH and ammonia on the sensitivities of four pathogens. Optimizing RH and ammonia

to establish aerosol pH and salinity that promotes pathogen die-off could yield energy-efficient inactivation strategies. Future experiments will further optimize ventilation rates and PAC usage to decrease airborne pathogens pathogens further.

**Conclusion**: Incorporating insights from indoor air science and biological studies offers a comprehensive approach to optimizing infection control strategies. This research addresses significant knowledge gaps by investigating the effects of RH, ammonia concentrations, ventilation rates, and PAC placements. The ongoing data analysis will yield findings that may inform energy-efficient strategies, thereby balancing health protection with sustainability. This research aims to promote sustainable indoor air quality management by providing practical, evidence-based recommendations supporting public health and energy conservation.

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