Abstract

The COVID-19 pandemic has underscored the critical need to understand and mitigate the spread of airborne pathogens in indoor environments. Traditional ventilation systems alone may not be sufficient to address this challenge, particularly in crowded or poorly ventilated spaces. Vulnerable individuals close to infected people emitting a respiratory cloud containing infectious load can inhale a pathogen dose, experiencing a more severe impact on their health compared to others breathing the mixed air in the same room. This study proposes an innovative approach using a portable desktop fan to control local airflow patterns that reduce the proximity risk of inhalation and subsequent transmission across short distances. This device has V-shaped air blades that alter the trajectory of particle-laden respiratory clouds emitted by infected individuals, significantly improving indoor air quality.

The research is divided into two phases. The first phase involves an in-depth analysis of the desktop fan used as a standalone device. This phase explores how the device influences indoor airflow pattern and particle dispersion within indoor environments in close proximity. Computational Fluid Dynamics (CFD) analysis using the Eulerian-Lagrangian method, which is validated through experimental data (carried out by Dr. Vincenzo Gentile and Eng. Luca Agnoletti is based on the testing methodology designed by Prof. Marco Simonetti) indicates that controlling local airflow through the V-shaped jet significantly reduces local particle concentrations up to 90%, compared to typical scenarios without local airflow control. This stage of the research establishes a foundational understanding of the standalone capabilities of desktop fans in enhancing indoor air quality.

The second phase examines the integration of desktop fans with traditional mixing mechanical ventilation systems. This integrated approach aims to investigate the combined benefits of direct and volumetric centralized airflow control to create a more effective air quality management strategy.

Several indoor configurations are simulated to assess the combined effects of local and centralized airflow control: a two-seater configuration evaluates the impact on particle concentration in small, close-proximity settings; a four-seater configuration examines medium-sized configurations and the effect of occupant density on particle dispersion; and a twenty-seater configuration analyzes large settings to identify the challenges and benefits of using multiple desktop fans. The methodology employed includes detailed CFD simulations that replicate realistic indoor environments using the Eulerian-Lagrangian approach, allowing for precise modeling of particle dynamics and airflow patterns and providing a robust framework for evaluating the effectiveness of the proposed strategies.

Key findings from this step indicate that properly positioned and adjusted desktop fan(s) can substantially reduce the transmission of respiratory particles. In the two-seater configuration, desktop fans improved air mixing and reduced localized particle concentrations of the susceptible person by over 100%. In larger settings, although the complexity of airflow dynamics presented challenges, notable improvements in air quality were still observed with the use of single and multiple fans for four-seater and twenty-seater scenarios, respectively.

This research contributes valuable insights into the potential of desktop fans to enhance indoor air quality and reduce airborne pathogen transmission, offering practical guidelines for optimizing their use in various indoor environments. The innovative approach of combining low-cost, portable devices with existing ventilation systems offers a flexible, energy-efficient, and effective solution for improving indoor air environments.