

Evaluating the Effectiveness of Various Infection Control Strategies in Classrooms

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Abstract

Airborne transmission of infectious diseases in classroom environments presents a significant challenge for public health, given the high density of occupants and the extended duration of indoor exposure. Numerous strategies have been proposed to mitigate the spread of airborne pathogens in such settings. Traditional approaches have focused primarily on enhancing ventilation, while more recent measures include the use of air cleaners, disposable masks, and the integration of localized control systems such as personal exhaust ventilation and physical barriers. Previous studies employing the Wells-Riley model have shown that improvements in ventilation can reduce the event reproduction number, R_0 , but the effectiveness of additional interventions varies considerably. For example, while disposable masks can lower infection risk by filtering exhaled and inhaled particles, their overall efficacy depends on factors such as filtration efficiency. Similarly, the use of air cleaners has been demonstrated to remove a significant fraction of airborne contaminants, yet their impact is influenced by operational parameters like clean air delivery rates. A novel approach that integrates personal exhaust ventilation with physical barriers has emerged as a promising strategy, as it directly targets the source of exhaled pathogens and limits cross-contamination among individuals. The present study aims to evaluate and compare the infection risk reduction capabilities of five distinct mitigation strategies in a classroom setting. By quantifying R_0 over the course of a typical one-hour class session, we assess the effectiveness of each strategy in controlling airborne transmission. The strategies include: (1) mixing ventilation alone, (2) ventilation with air cleaners, (3) ventilation with disposable masks, (4) a hybrid strategy combining masks, air cleaners, and ventilation, and (5) an integrated strategy incorporating personal exhaust ventilation with physical barriers along with ventilation. This comparative analysis is intended to provide a robust framework for decision-makers in educational settings, helping them select interventions that most effectively reduce infection risk. The study was conducted in a typical classroom with dimensions of 9 m in length, 6 m in width, and a height of 3.3 m, accommodating 30 occupants, including students and teachers. The classroom is equipped with a mechanical ventilation system operating at a flow rate of 148 Liters per second (L/s), running for 6 hours per day across whole academic year. This operational schedule ensures adequate indoor air quality, particularly in the context of reducing airborne transmission risks. Each case was calculated over the entire school year, from September to June, allowing for a detailed analysis of the system's performance under realistic conditions. Results from the infection risk analysis demonstrate that while basic ventilation is insufficient to control pathogen spread, strategies that incorporate additional measures significantly reduce R_0 . In particular, the multi-layered approaches in Cases 4 and 5 yield the lowest R_0 values, indicating superior infection control performance. These findings offer valuable insights for educational institutions seeking to implement effective, evidence-based infection mitigation measures in classroom settings.

Keywords

Infection risk, Air cleaner, Mask, Physical barriers, Personal exhaust ventilation.