COVID-19 dispersion in naturally-ventilated classrooms: a study on inlet-outlet characteristics

Citation for published version (APA):
Abbas, G. M., & Gursul Dino, I. (2022). COVID-19 dispersion in naturally-ventilated classrooms: a study on inlet-outlet characteristics. *Journal of Building Performance Simulation*, *15*(5), 656-677. https://doi.org/10.1080/19401493.2022.2063946

Document license:
TAVERNE

DOI:
10.1080/19401493.2022.2063946

Document status and date:
Published: 03/09/2022

Document Version:
Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

the scenarios' simulation results, such that scenarios with the same H_{inlet} show very similar CC values, distribution and stratification behaviour. Our results also show that the results of $CC_{int(120-180)}$ and CC_{total} may vary widely due to different contaminant stratification behaviour as a result of different inlet and outlet heights. Nevertheless, no correlation is observed between the H_{outlet} and contaminant concentration according to our simulation results.

The vertical asymmetry of the opening heights has a considerable impact on CC. There is an inverse correlation between the CC_{total} and the difference between the inlet and outlet. The highest rates of discharge are observed in the scenarios with lower H_{inlet} and maximum difference between the inlets and outlets. These results are also in line with the principles of stack ventilation and the Bernoulli effect, which suggest that an increase in the difference between the inlet and outlet openings can also increase the effectiveness of indoor ventilation. The greater inlet–outlet height difference results in greater air pressure differences, accelerating discharge rates.

Finally, in our analyses, the occupants' proximity to the inlets did not reduce the infection risks because of the air recirculation occurring nearby the inlets. Likewise, the occupants' proximity to P_{contam} did not always result in high infection risks, because of the asymmetric airflow allowing the zones outside the area between the inlets and the outlet to remain less contaminated. We conclude that the proximity to inlets or P_{contam} is not determinant in occupants' infection risk.

This research points to several practical insights based on the simulation results to reduce COVID-19 transmission risks. First, the adjustment of the opening heights can be highly effective in reducing infection risks in existing buildings. Placing inlet openings at lower levels of the room and increasing the inlet–outlet height difference can help discharge the contaminated air. Also, locating the inlet at the level of the breathing zone and perpendicular to the prevailing wind direction can be effective for accelerating the discharge and reducing occupants' contaminant exposure. However, it should be considered that dynamic airflow may also result in recirculation in the room while transporting P_{contam}. Therefore, recirculation zones, which are infection-vulnerable zones in the room, must be identified, and their use must be determined accordingly. This strategy can further reduce the infection risks by guiding indoor circulation and determining the safer zones for the occupants. Similarly, in addition to the vertical adjustments, the horizontal adjustment of the openings for asymmetric airflow behaviour can provide uncontaminated zones with lower infection risks. Second, the COVID-19 pandemic revealed that the current building occupancy practices need to be revised for the existing buildings. The required time for re-occupancy must be calculated for each specific room configuration. The presented pipeline can also be implemented for the determination of re-occupancy. We evaluate the risk of infection for a particular time for CC. However, CC values can be insufficient in quantifying the discharge performance and determining the re-occupancy since complete discharge may not happen during the occupancy. Therefore T_{dis} can be considered as a metric for determining the re-occupancy.

5. Conclusion

Educational facilities have a significant impact on the spread of airborne infections. Investigating the COVID-19 transmission for classrooms is an urgent need to continue educational activities without interruptions. Educational facilities commonly rely on natural ventilation, which also acts as a preventive measure against infection risks. However, the impact of natural ventilation on COVID-19 dispersion in buildings for different inlet–outlet configurations remains unclear. Our paper addresses the need to develop a broader understanding of the correlation between window height, natural ventilation, and the aerodynamic behaviour of COVID-19 dispersion. We performed simulation-based analyses on indoor air contamination in a naturally ventilated classroom contaminated by COVID-19. We implemented a simulation pipeline that integrates energy, outdoor CFD, and contaminant transport simulations that can calculate contaminant concentration using environmental parameters. There are also alternative methods for indoor contaminant analysis. However, compared to the implemented pipeline, these methods can be regarded as limited as they assume contaminant concentration as constant, steady, and randomly distributed and neglect spatial variations of the contaminant dispersion if they are not augmented by CFD simulations. Also, the implemented pipeline can allow the analysis of different inlet–outlet configurations by integrating a 3D parametric design environment. Also, based on the generated 3D parametric models, the pipeline also benefitted from the already integrated environments used to model and perform simulations. Integrating energy and outdoor CFD analysis increased precision of analysis results by calculating wind pressure coefficients and indoor air temperatures for each scenario. Nine scenarios representing different inlet and outlet heights are modelled and simulated using the pipeline. We calculated contaminant concentration, time of discharge, and time of infection and explored the correlations between these parameters.

Within the scope of this study, two limitations were identified. First, our study focuses on a specific building