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Infectious airborne risk measurement in a classroom

Măsurarea riscului de infecții în aer într-o sală de clasă

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Abstract. *This study investigates the airborne transmission risk of infectious diseases in a classroom setting, aiming to develop a comprehensive risk measurement model. The research employs a combination of computational fluid dynamics simulations, viral load measurements, and epidemiological data to analyze airflow patterns, ventilation efficiency, and viral dispersion in classrooms. Real-time monitoring of air quality, temperature, and humidity is integrated to establish a risk assessment framework. The findings reveal the significance of proper ventilation and strategic classroom layout in mitigating airborne disease transmission. This research offers practical insights for educational institutions to implement informed strategies to minimize airborne risks, ensuring a safer learning environment.*

Keywords: Ventilation, Classroom layout, Aerosol dynamics, Viral load, Risk assessment

1. Introduction

The ongoing global COVID-19 pandemic has highlighted the critical need for understanding and mitigating infectious airborne risks in various indoor settings. Among these, classrooms present a unique challenge, as they serve as essential spaces for learning and social interaction while potentially facilitating disease transmission. Thus, there is an increasing demand for evidence-based strategies to minimize the risk of airborne infections in educational environments.[1, 2]
In recent years, the research on infectious airborne risk measurement in classrooms has expanded rapidly due to the COVID-19 pandemic. Several key areas of investigation have emerged, with a focus on understanding transmission dynamics and implementing effective mitigation strategies. These areas include:

1. Airflow and Ventilation Studies: Research has emphasized the importance of proper ventilation to mitigate the spread of airborne pathogens in indoor environments. Computational fluid dynamics simulations have been employed to model airflow

patterns, revealing the significance of air exchange rates, filtration systems, and natural ventilation strategies (e.g., opening windows and doors) in reducing airborne transmission risk [3, 4].

2. Classroom Layout and Occupancy: Studies have explored the impact of classroom configurations and occupancy levels on the risk of airborne infections. By analyzing different seating arrangements, desk spacing, and occupant behavior, researchers have identified optimized layouts that minimize disease transmission [5, 6].
3. Aerosol and Droplet Dynamics: The dispersion and deposition of respiratory droplets and aerosols generated by talking, coughing, or sneezing have been investigated to understand their role in disease transmission. These studies have shown the significance of droplet size, evaporation rate, and environmental factors (e.g., temperature, humidity) in pathogen persistence and exposure risk [7, 8].
4. Viral Load and Infectious Dose: Research has focused on quantifying viral load in indoor air and surfaces, as well as the relationship between exposure dose and infection probability. By understanding the infectious dose required for transmission, researchers can better inform risk assessment models and mitigation strategies [9, 10].
5. Risk Assessment Frameworks: Integrating the above factors, researchers have developed comprehensive risk assessment models to evaluate airborne disease transmission in classrooms. These models incorporate real-time monitoring of environmental parameters and account for various intervention strategies (e.g., mask-wearing and vaccination status) to inform decision-making and policy recommendations [3, 6].

The ongoing state-of-the-art research in infectious airborne risk measurement in classrooms has dramatically advanced our understanding of transmission dynamics and provided valuable insights for implementing effective mitigation strategies. Future research will continue to refine these models, incorporating emerging knowledge on pathogen characteristics, human behavior, and technological innovations to ensure safer learning environments.

2. Material and method

In this study, we focus on infectious airborne risk measurement in a classroom setting, aiming to develop a comprehensive risk assessment model. Airborne transmission of pathogens such as SARS-CoV-2 and influenza viruses poses a significant threat to public health, particularly in enclosed spaces with limited ventilation and prolonged human contact. Understanding the factors influencing airborne disease transmission in classrooms is vital for formulating effective preventive measures and ensuring a safe learning environment.

We use a multidisciplinary approach that combines simulations of computational fluid dynamics, measurements of viral load, and epidemiological data to find out how ventilation, classroom layout, and how people act affect the spread of airborne pathogens. Moreover, we incorporate real-time monitoring of air quality, temperature, and humidity to establish a robust risk assessment framework.

The results of our research contribute to the growing body of knowledge on infectious disease transmission in indoor environments, providing valuable insights for educational institutions, policymakers, and public health authorities. By implementing informed strategies to minimise airborne risks, we can enhance the safety and well-being of students and teachers, fostering an environment that supports effective learning and engagement.

The following materials and methods outline the steps taken to model, simulate, and evaluate various scenarios to understand the impact of classroom configurations, ventilation systems, and occupant behaviors on airborne disease transmission:

● Classroom Geometry and Configuration: A three-dimensional (3D) model of a typical classroom is created, accounting for dimensions, furniture (e.g., desks, chairs), and architectural features (e.g., windows, doors, and vents). Different classroom layouts and seating arrangements are also considered, representing various occupancy levels and spatial configurations.

● Ventilation System Modelling: The ventilation system in the classroom is modelled, specifying supply and exhaust airflows, filtration efficiencies, and air exchange rates. Different ventilation strategies, such as natural (e.g., opening windows and doors) and mechanical (e.g., HVAC systems with HEPA filters), are investigated.

● Occupant Behaviour: Occupants' behaviour (students and teachers) is incorporated into the model, accounting for activities such as talking, coughing, or sneezing. The generation, dispersion, and deposition of respiratory droplets and aerosols are modelled using appropriate source terms and boundary conditions.

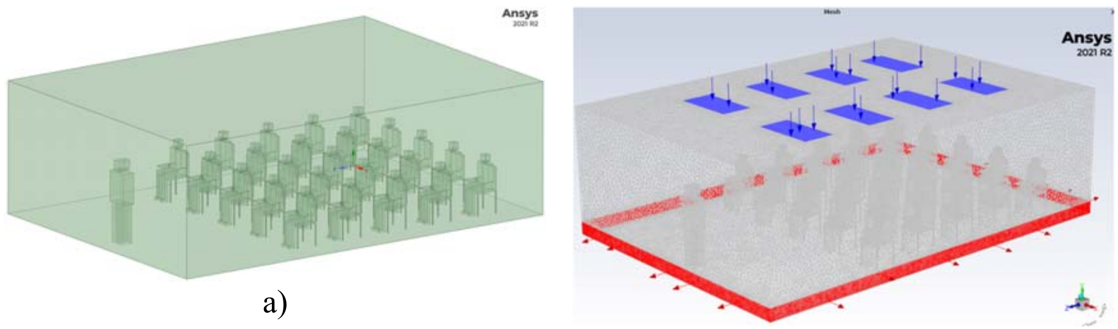
● CFD Simulation Setup: Governing fluid flow, heat transfer, and mass transfer (e.g., Navier-Stokes equations, energy equations, species transport equations) are solved using a CFD software package. The model is broken up into smaller pieces using an appropriate numerical method (like the finite volume method), and turbulence is modelled using an appropriate method (like Reynolds-averaged Navier-Stokes (RANS) equations with k-epsilon or k-omega turbulence models).

● Boundary Conditions and Parameters: Boundary conditions for airflow, temperature, humidity, and aerosol/droplet sources are specified based on experimental data or literature values. Environmental parameters such as ambient temperature and humidity are also considered.

● Simulation Scenarios: Various scenarios are conducted, considering different classroom layouts, ventilation strategies, and occupant behaviors. The impact of interventions such as mask-wearing and vaccination status is also assessed.

● Post-processing and Analysis: The CFD simulation results are post-processed to visualise airflow patterns, temperature and humidity distributions, and aerosol/droplet concentrations. Key performance indicators (KPIs), such as air exchange rates, exposure risks, and infection probabilities, are calculated to evaluate and compare different scenarios.

● Validation and Sensitivity Analysis: The CFD model is validated against experimental data or literature values, ensuring the accuracy and reliability of the results. Sensitivity analyses are performed to identify the most critical factors influencing airborne disease transmission and to assess the robustness of the model predictions.



a) b)

Fig. 1. a) Classroom geometry; b) boundary conditions and geometry meshing

Covid 19 airborne risk measurement using ANSYS Fluent software in a classroom is the subject of this simulation. We carry out this CFD project and do a CFD analysis to look at it.

The Corona (COVID-19) virus is currently regarded as the greatest threat to humankind worldwide since it not only poses a threat to human health but also has a high propensity for spreading between sick and healthy individuals. In a confined public setting, a patient's breathing without a mask spreads the infection to their neighbours. Maintaining a suitable social distance between people in such locations is one of the doctors' crucial recommendations for minimising viral transmission.

For instance, proximity between a student's seat at a university and a student in a classroom can enhance the likelihood that a patient will spread the COVID-19 disease to others nearby.

Through this effort, pupils who are sick or coronavirus carriers in the classroom can inhale contagious air. This project intends to look into how well the ventilation system in the classroom works to clean the air and remove pollutants.

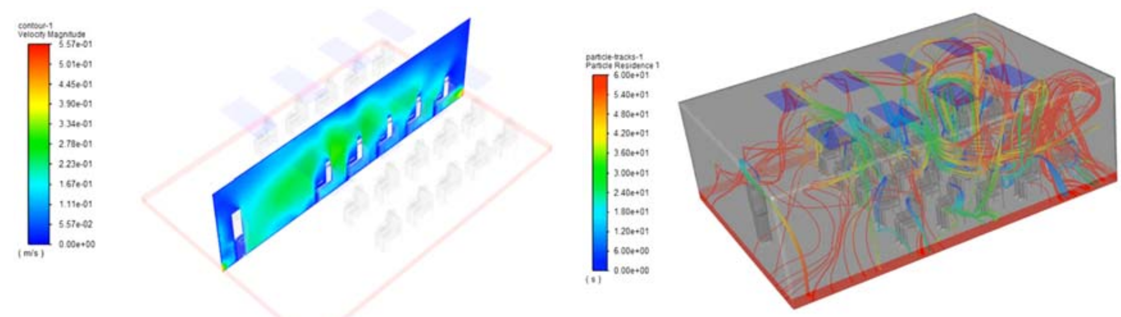
This concept makes use of a ventilation system with numerous vents for the entry of fresh air flow from the classroom's ceiling and numerous panels for the escape of the old airflow at the bottom of the sidewalls of the classroom.

Design Modeller software is used to draw the geometry of the current model. A student is represented on each of the chairs in this model's computational zone, representing a classroom with chairs. A surface is designated as the mouth's source for breathing and viral transmission for each student. The ANSYS Meshing program then meshes the model. 2745511 cells have been produced, and the model mesh is unstructured.

3. Results

The outcomes of the two scenarios—where the teacher is ill and when it is one of the students—are considered. Therefore, regulating mechanical ventilation carries a more significant risk of contamination, which may be decreased when using natural ventilation without wind. There are two causes for this decrease in risk. The first is an increased ventilation rate, which results in a decrease in droplet concentration. (Figure 2)

The second is a decrease in the surrounding relative humidity. Comparing the CFD data reveals that natural ventilation results in significantly lower average ambient humidity than mechanical ventilation. The simulations were run using entering air at 20°C and 40% relative humidity. This is typical of the late spring and early summer climate in Europe. Since the relative humidity of the entering air would be reduced by heating it, these conclusions would still be valid in colder climates. They might be questioned in a hot, muggy environment.



a) b)

Fig. 2. a) Contours of Velocity Magnitude; b) Particle Tracking Dispersion

4. Discussion

The COVID-19 pandemic outbreak has highlighted the significance of creating a safe and healthy indoor environment, such as by boosting outdoor air delivery to diluted contaminants (viruses). This is a complex undertaking, especially for naturally ventilated buildings when the weather outside is erratic. In this situation, using cost-effective ventilation solutions is crucial to enhancing the effectiveness of air dispersion and reducing the spread of infectious diseases. This study focuses on changing the size and placement of windows that open as well as how they work with fans. Utilizing the best window apertures and installing window-integrated fans will increase ventilation efficiency and reduce the risk of infection. This study demonstrated how a supply fan integrated into the window opening could create a safe and healthy indoor environment in a naturally ventilated area. This approach is affordable and straightforward to implement in practically every classroom in developed and developing nations. However, in practical applications, it is also essential to consider the potential effects of fan noise.

5. Conclusion

After simulation, particle tracking of the virus particles is obtained based on the residence time of 60 s. Also, 2D and 3D contours of temperature and air velocity inside the classroom have been obtained. The flow path lines are also obtained in 3D.
The results show that this ventilation system is inappropriate for the classroom and increases the risk of virus dispersion. This is because the virus particles spread entirely inside the classroom. In other words, the classroom ventilation system's mechanism helps the virus survive in space.

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