Classroom Ventilation Methods to Prevent Particle Transfer

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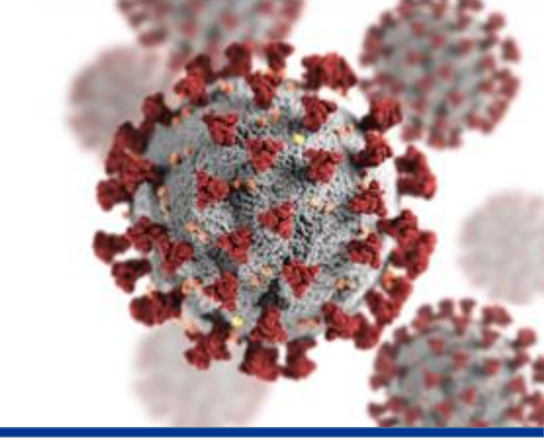
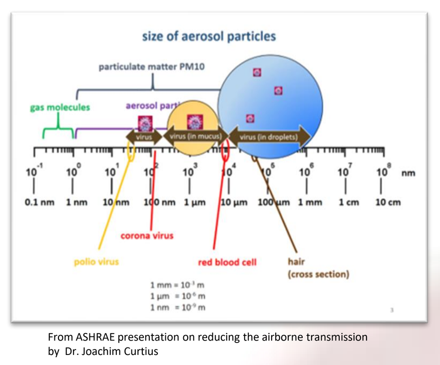


Background

COVID-19 has demonstrated the need for our society to adapt and be able to prevent airborne transmission of harmful particles such as:

- Pathogens such as viruses and bacteria
- Allergens
- Pollution and other irritants



Using CO_2 as a tracer gas, Prof. Todd Gross began research into transmission prevention techniques by evaluating certain rooms on campus.

This senior project team has continued his work during the 2020-2021 academic year, aiming to test several scenarios in a classroom, a laboratory, and a lecture hall.

Research Statement

Experimentally and numerically investigate ventilation and airflow strategies to reduce particle transmission in classrooms by a factor of 100-1000.

- Mitigation techniques such as physical barriers, air curtains and supplemental exhaust systems are to be tested to determine the most effective method
- Computational Fluid Dynamics (CFD) modeling is used to replicate experiments and simulate CO_2 concentration

Mitigation Methods

Ambient Mixing

- Using box fans to dilute contaminated air
- Widely accessible mitigation technique
- Easiest to implement

Physical Barriers

- Frontal and lateral
- Disrupting airflow to limit particulate transfer
- Currently one of the most common applications

Supplemental Exhaust System

- Providing occupants with snorkels to exhaust contaminated air
- Constructed from a 750 CFM inline duct fan and 4" duct hose
- Costly and intrusive to implement for each occupant

Methodology

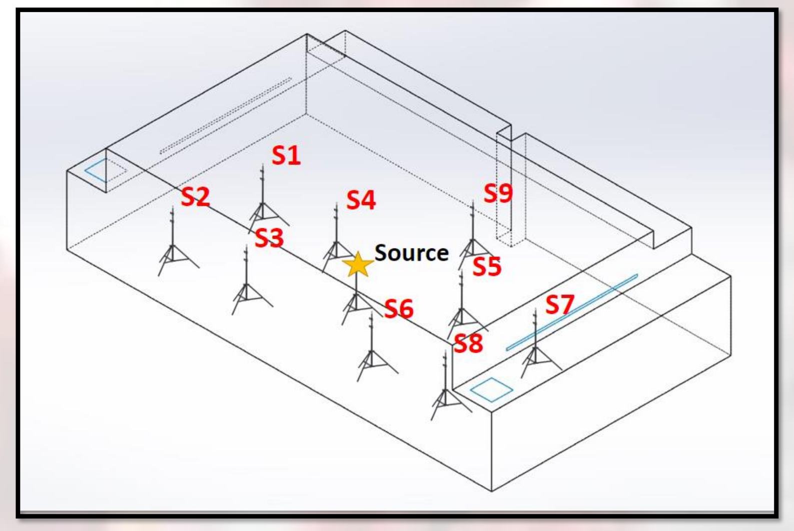
By testing various mitigation methods and ventilation scenarios in academic settings, airflow interactions and effective safety measures can be better understood. To do this, one lab, one lecture hall, and one classroom were tested five times: baseline, lateral barriers, frontal barriers, snorkel, and ambient mixing.

Testing Mitigation Techniques:

- Place sensors at student positions and a height of 1 meter to replicate a classroom scenario
- Applicable mitigation technique implemented
- Allow room to come to steady-state conditions ~ 20 min
- Release CO_2 at 7.1 LPM
- Shut off CO_2 after 30 min
- Stop recording after another 30 min

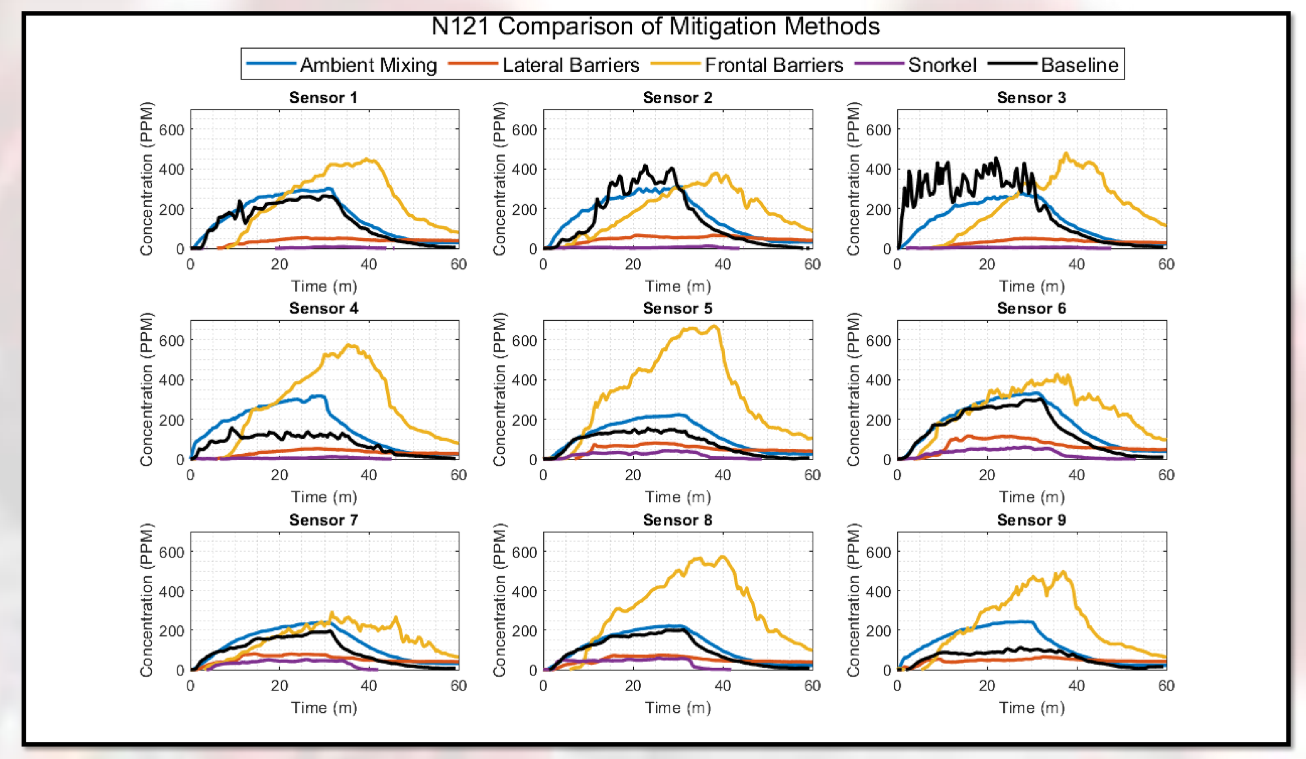
Results - Kingsbury N121 (Classroom)

N121 Sensor Layout



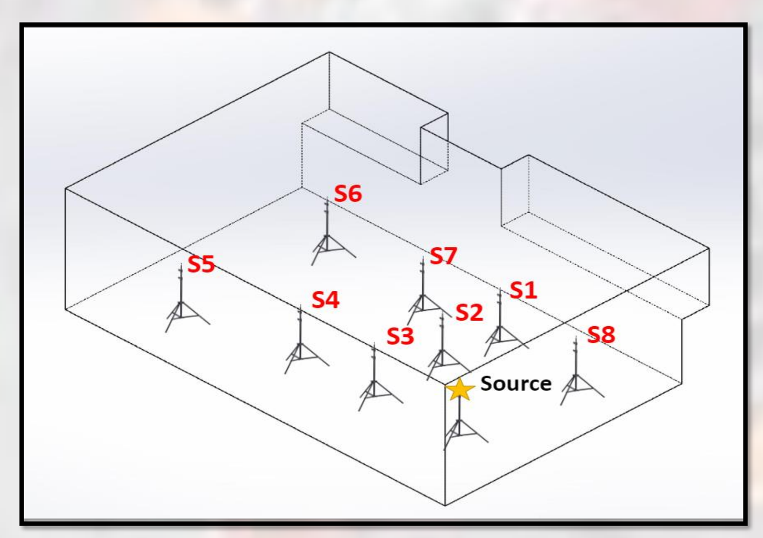
KINGS N121	Baseline	Ambient Mixing	Lateral Barriers	Frontal Barriers	Snorkel
Max Concentration (PPM)	454	332	115	669	60
Factor of Decrease		1.37	3.95	0.68	7.57

Comparison of Mitigation Methods



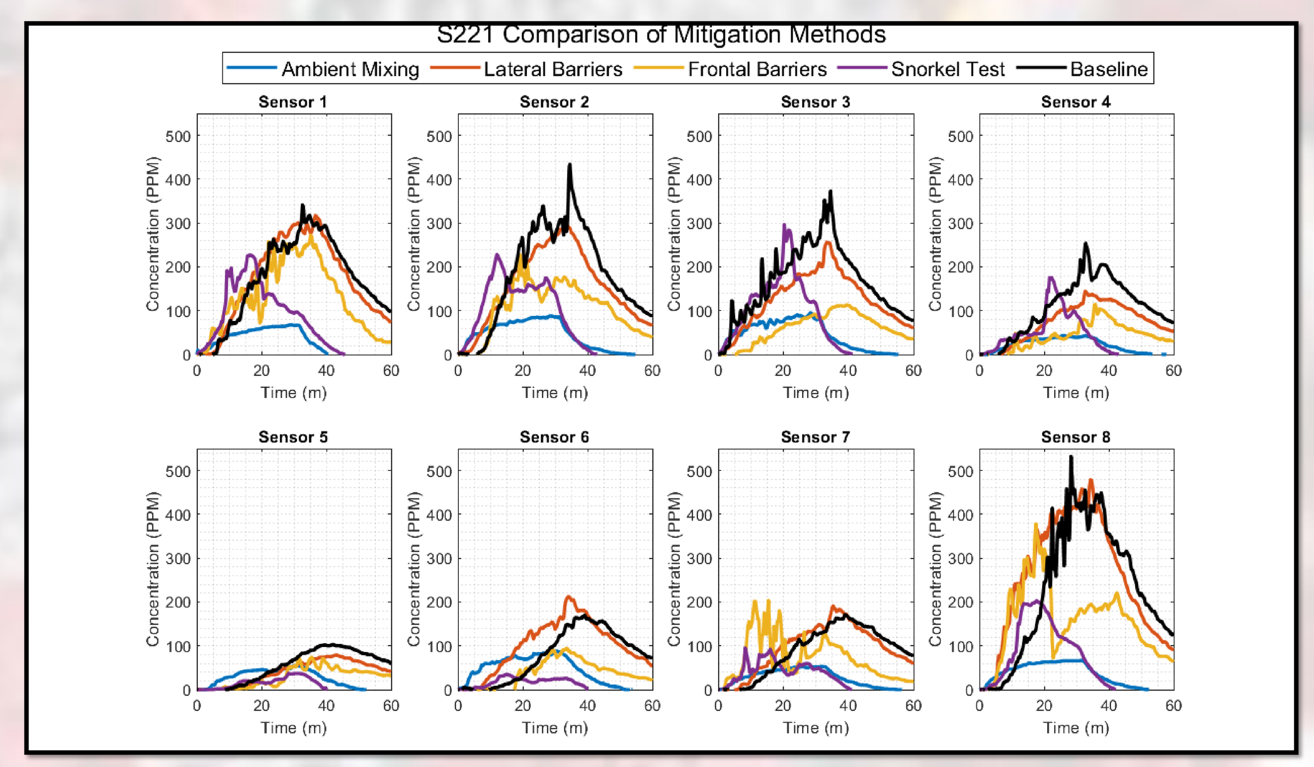
Results - Kingsbury S221 (Laboratory)

S221 Sensor Layout



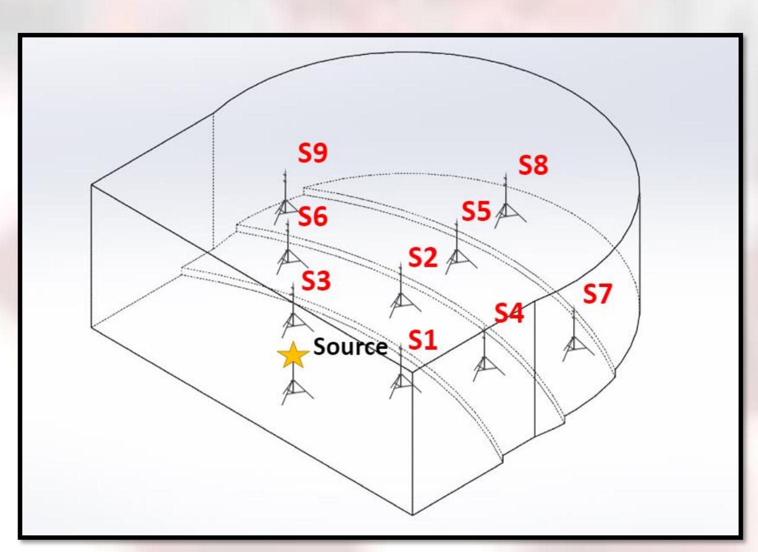
KINGS S221	Baseline	Ambient Mixing	Lateral Barriers	Frontal Barriers	Snorkel
Max Concentration (PPM)	532	88	479	378	296
Factor of Decrease		6.05	1.11	1.11	1.80

Comparison of Mitigation Methods



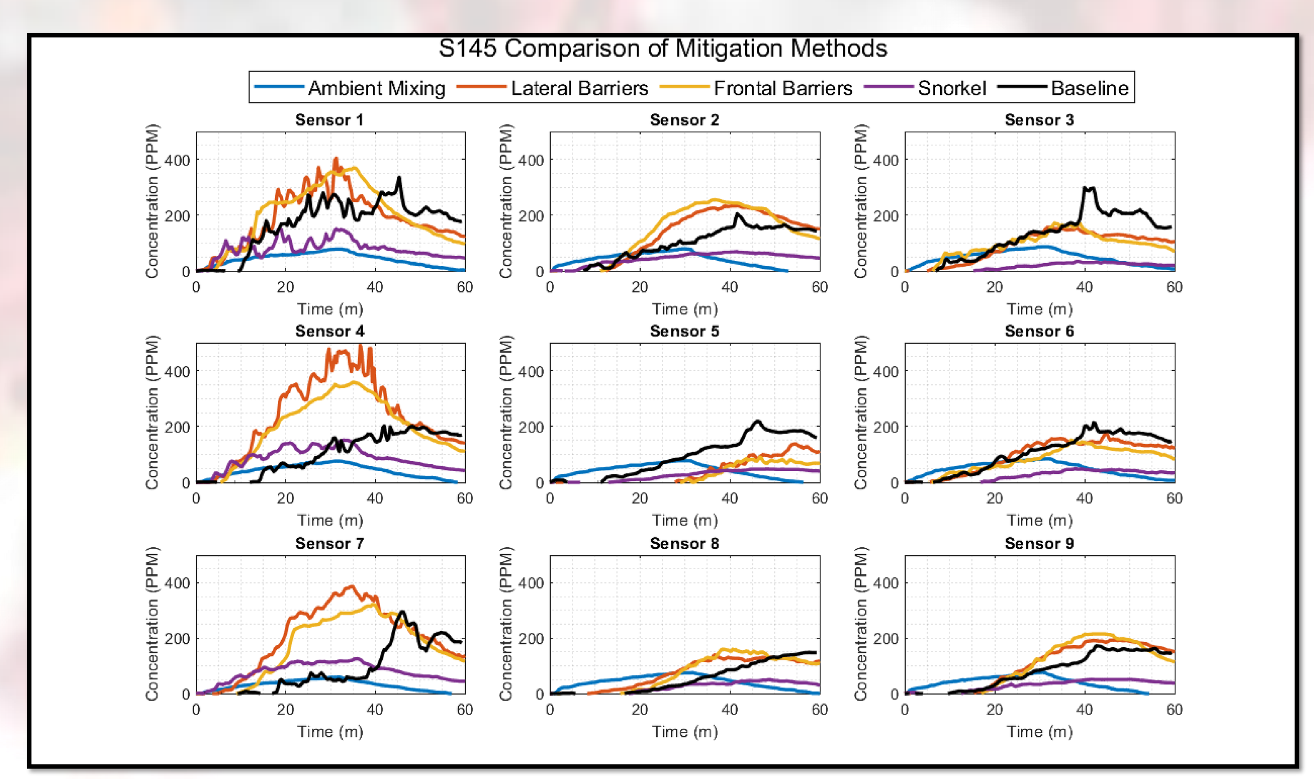
Results - Kingsbury S145 (Lecture Hall)

S145 Sensor Layout



KINGS S145	Baseline	Ambient Mixing	Lateral Barriers	Frontal Barriers	Snorkel
Max Concentration (PPM)	335	86	490	369	151
Factor of Decrease		3.90	0.68	0.91	2.22

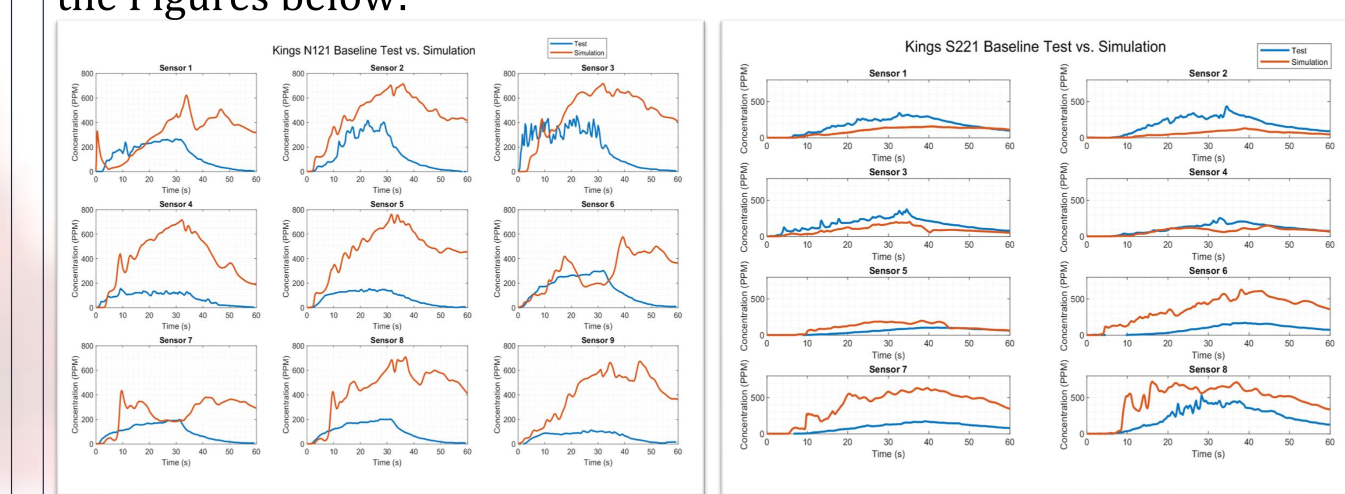
Comparison of Mitigation Methods



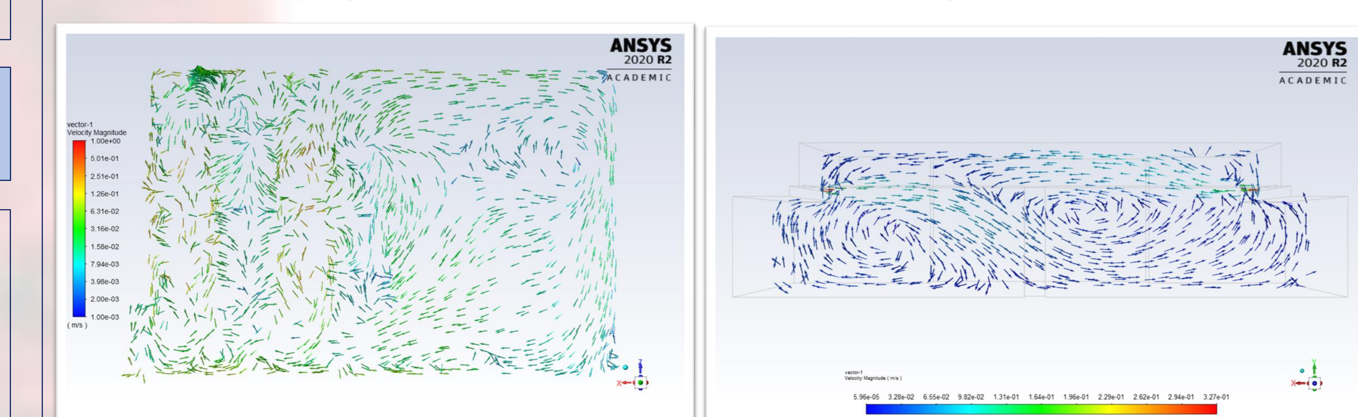
Results – CFD Simulations

Equivalent CFD simulations using the geometry of Kingsbury N121 and S221 were performed using ANSYS Fluent. A species transport model was employed to simulate the movement of CO_2 gas.

Simulated concentration results are compared to empirical results in the Figures below:



Shown below are velocity vector diagrams illustrating the airflow patterns of Kingsbury S221 (left) and N121 (right):



Conclusions

There is no one solution for all spaces. Different ventilation patterns and geometries necessitate different methods.

Ambient mixing and the supplemental exhaust were the most universally effective, but still had varying results from room to room:

- The fan method was an effective cleaning method
- Ventilating the contaminated air from the space protected occupants most successfully but is also the least practical method employed

Barriers had very mixed results:

- Lateral barriers extremely effective in some spaces, harmful in others
- Frontal barriers very effective in some spaces, extremely harmful in others
- In one space, implementation of barriers had little to no effect

CFD simulations were able to predict CO_2 concentration within a reasonable error margin while displaying similar trends to the experimental data. Considering the extent of simplification made in the room geometry, mesh density, and replicating the experiment, these models can be useful in evaluating hypothetical transfer mitigations without setting up experiments.

Acknowledgements

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