

Musician and Performers Aerosol Study Phase I: Exploratory Testing



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U of Maryland Team: Srebric, Milton, Zhu
Study Chairs: Weaver (NFHS), Spede (Clemson)



Recommendations based on first phase of testing can be found here:
<https://www.nfhs.org/articles/unprecedented-international-coalition-led-by-performing-arts-organizations-to-commission-covid-19-study/>

Lead Funders



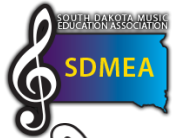
Contributing Organizations



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Short Primer on Aerosol Transmission and Exposure Risk Mitigation

THE CONVERSATION
Academic rigor, journalistic flair

Search analysis, research, academics...

COVID-19 Arts + Culture Economy + Business Education Environment + Energy Ethics + Religion **Health** Politics/Election '20 Science + Technology




How to use ventilation and air filtration to prevent the spread of coronavirus indoors

August 10, 2020 8:09am EDT

Open windows are the easiest way to ventilate a room. Justin Paget / Digital Vision via Getty Images

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The vast majority of SARS-CoV-2 transmission occurs indoors, most of it from the inhalation of airborne particles that contain the coronavirus. The best way to prevent the virus from spreading in a home or business would be to simply keep infected people away. But this is hard to do when an estimated 40% of cases are

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Coronavirus drifts through the air in microscopic droplets – here's the science of infectious aerosols

April 24, 2020 8:22am EDT

From your lungs into the air around you, aerosols carry coronavirus. Peter Dazeley/The Image Bank via Getty Images

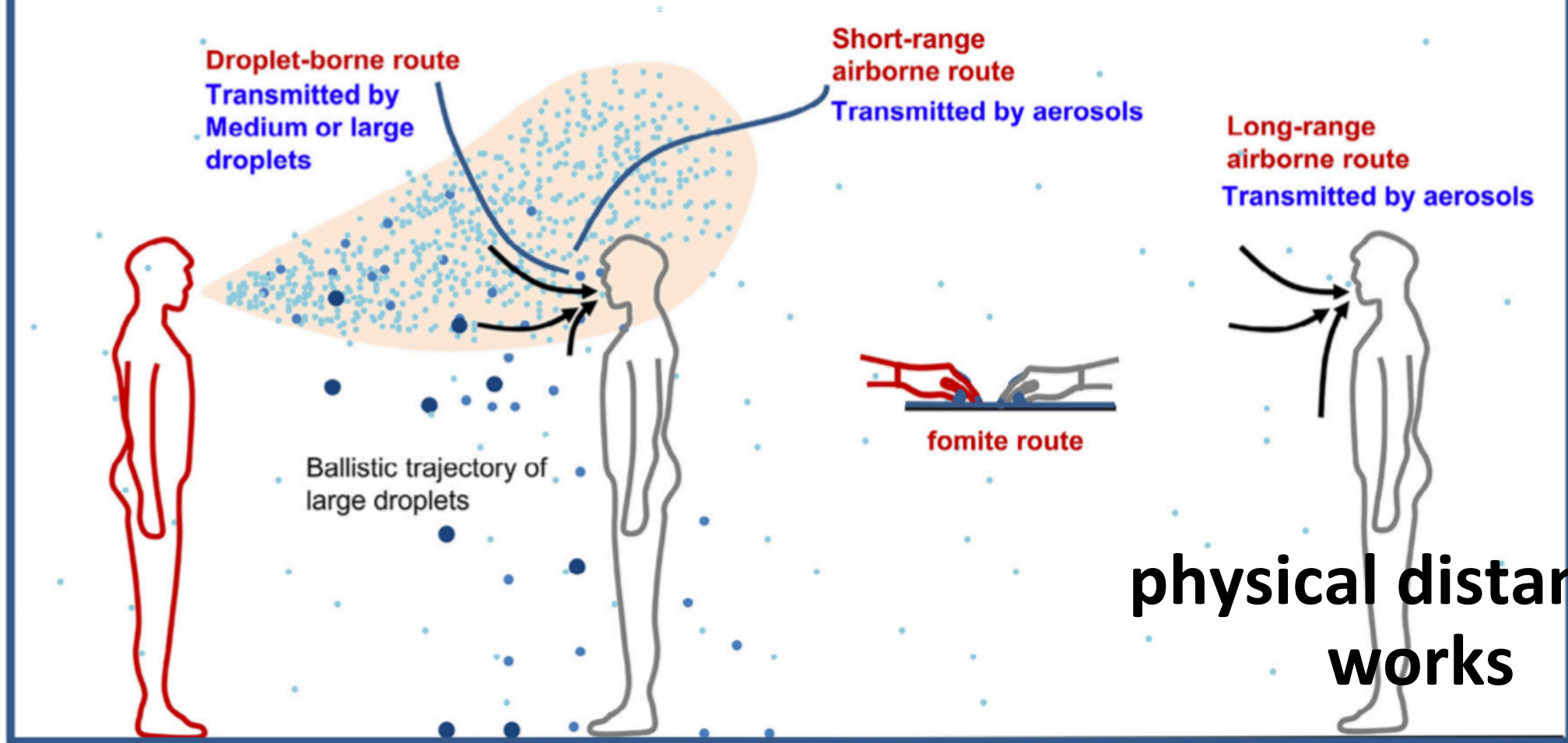
Email 98
Twitter 3.9k
Facebook
LinkedIn

During the 1970s when I was growing up in Southern California, the air was so polluted that I was regularly sent home from high school to “shelter in place.” There might not seem to be much in common between staying home due to air pollution and staying home to fight the coronavirus pandemic, but

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How Airborne Transmission Occurs

Wei, J., Li, Y.,
2016. Airborne
spread of
infectious agents
in the indoor
environment.
American Journal
of Infection
Control 44, S102–
S108



**physical distancing
works**

2 m = 6 ft can keep you out of the short-range
aerosol transmission plume

surgical face masks could prevent transmission of human coronaviruses and influenza viruses from symptomatic and asymptomatic individuals

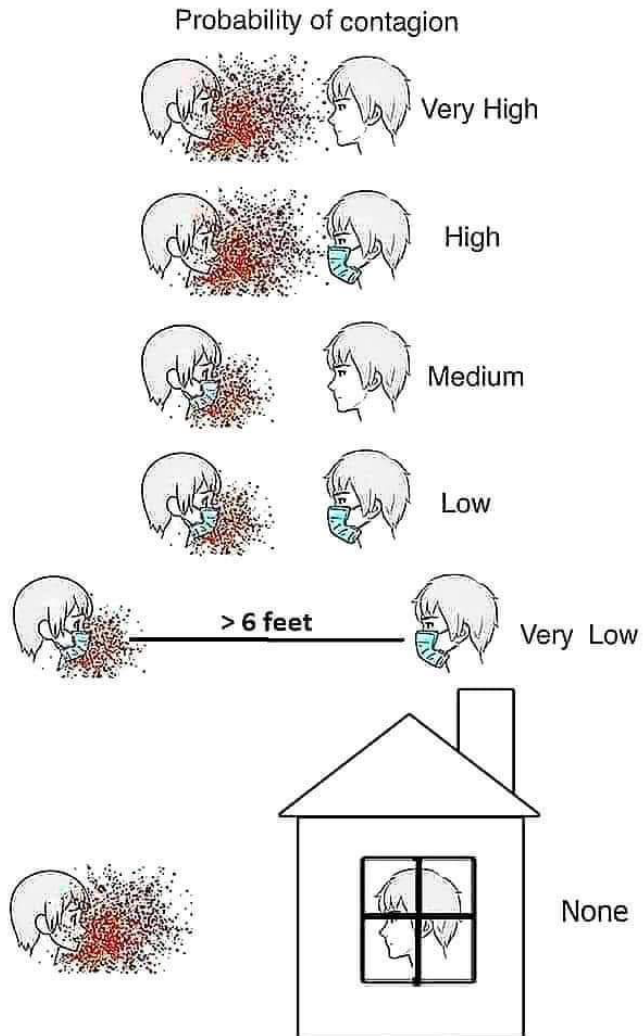
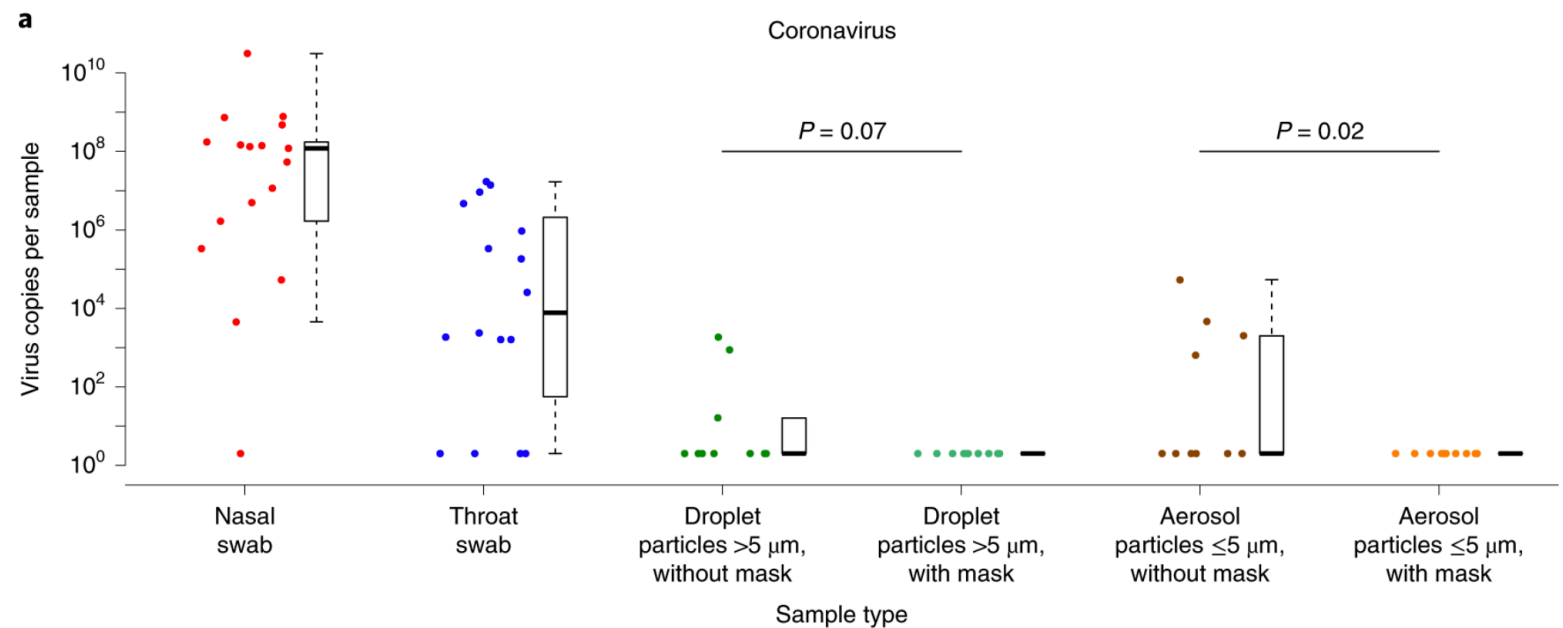


Fig. 1: Efficacy of surgical face masks in reducing respiratory virus shedding in respiratory droplets and aerosols of symptomatic individuals with coronavirus, influenza virus or rhinovirus infection.

From: [Respiratory virus shedding in exhaled breath and efficacy of face masks](#)



Leung, et al., 2020. Respiratory virus shedding in exhaled breath and efficacy of face masks. *Nature Medicine*, pp.1-5.

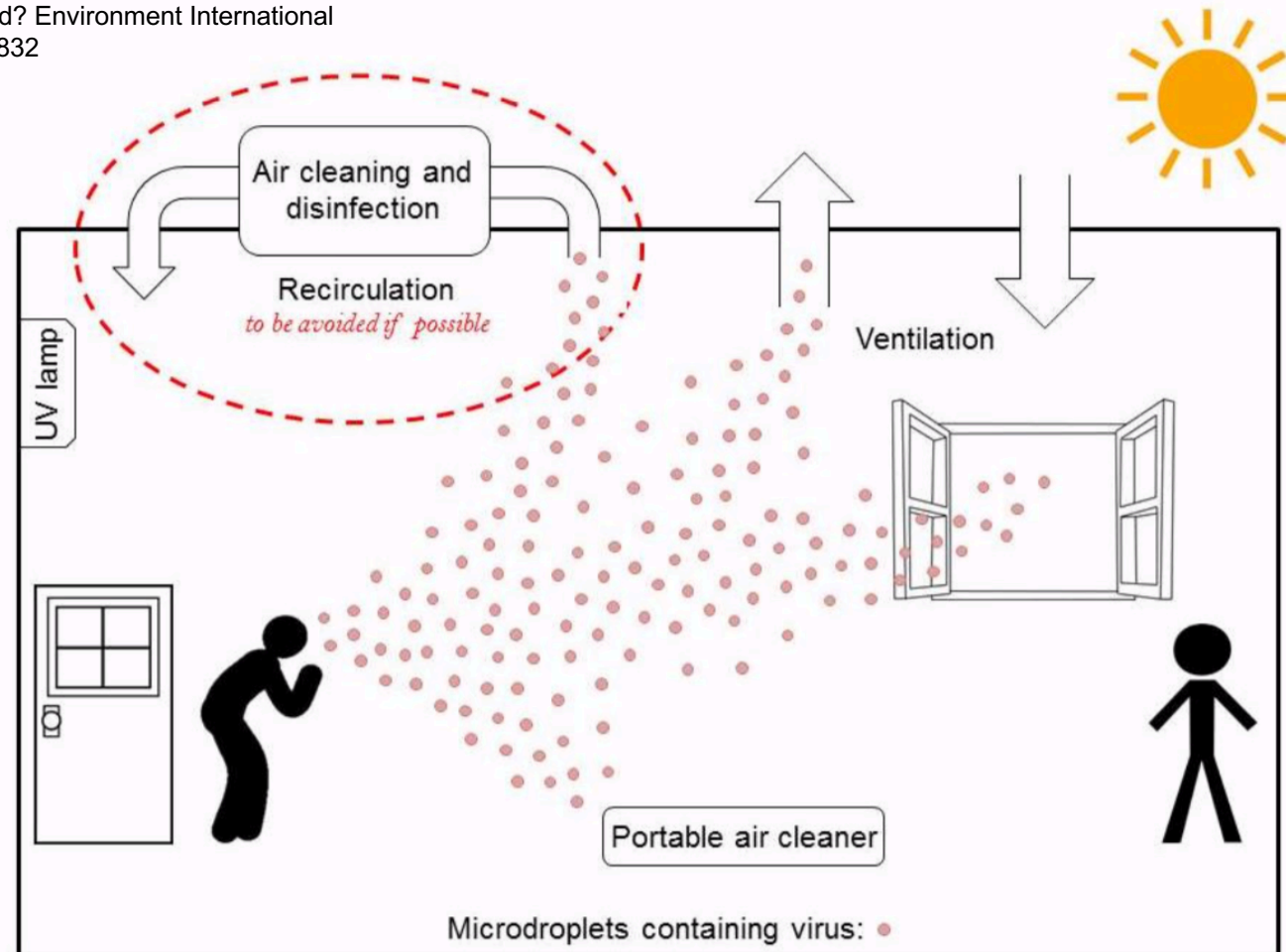
Compelling evidence to show significant transmission in crowded **poorly ventilated** spaces

- Clusters in Japan from in fitness gyms, restaurant boat on a river, hospitals, snow festival tented restaurants
- Ski-chalet associated transmission in France, ski-gondola transmission in Idaho
- Singapore Clusters from tourist shop, banquet dinner, church
- Church-associated clusters in South Korea and Washington state
- 3 family clusters in air-conditioned restaurant
- Among 7000+ cases in China 1 involved 2 in conversation outdoors

Ordinary speech aerosolizes significant quantities of respiratory particles. Some people are also super emitters (10-min conversation = cloud of 6000 aerosol articles)

Short-range airborne route dominates during talking and coughing during close contact (< 2 m). Large droplet dominates when > 100 μm and within 0.2 m while talking

Morawska et al 2020. How can airborne transmission of COVID-19 indoors be minimized? Environment International 142, 105832



- **Ventilation** provides outdoor air to a space by natural or mechanical means
- Controls how quickly room air is removed/replaced over time
- Ventilation rates recommended for different spaces by ASHRAE
- Every space is different
- Homes/schools/office buildings

Air cleaners really work!



Clean Air Delivery Rate

Certified Rating

From air cleaner to air cleaner, compare the CADR numbers. First, look at suggested room size. Then refer to the dust, tobacco smoke and pollen Clean Air Delivery Rate (CADR) numbers. The higher the numbers, the faster the unit filters the air.

This air cleaner is suggested for use in a single closed room up to 120 square feet.

Room size ratings conform to the AHAM Certification Program criteria of 80% smoke reduction. Higher Clean Air Delivery Rates provide improved performance in all room sizes. Portable air cleaners will be much more effective in rooms where all doors and windows are closed.

Dust: 80 Tobacco Smoke: 80 Pollen: 80

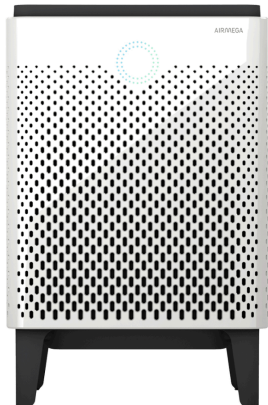
These values represent performance that can be expected within the first 72 hours of operation. Subsequent performance may vary with use.

Association of Home Appliance Manufacturers **AHAM**

Airmega 300S Smart HEPA Air Purifier by Coway

Model: 300S SKU: co5313 ★★★★★ (9 Reviews) Ask Question

VIDEO



List Price: \$649.00

Sale: \$515.00

Free 3 Day Delivery to 80309

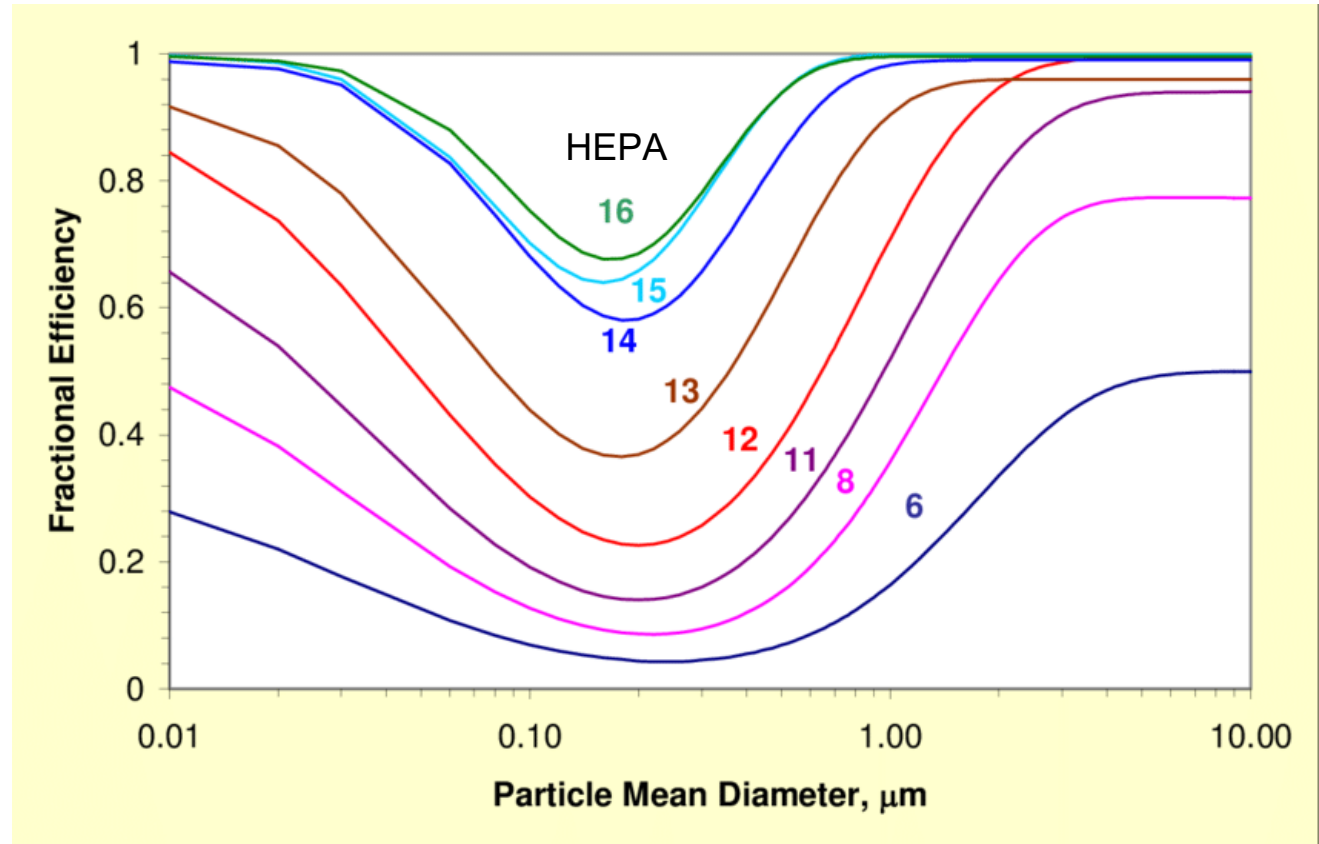
In Stock - Order Now. Your item will ship Thursday, Apr 30th.

Quantity: 1

Add To Cart

Or as low as \$23.77 / Month*

CADR = 260
 Max flow = 340 cfm
 Area for cleaning? 700 ft²



Increase (clean) outdoor air supply

- building ventilation can be as effective as public health interventions
- existing ventilation rates may be too low to prevent or control airborne infectious diseases in indoors
- and might need to be increased by 10x

Gao, X., Li, Y. and Leung, G.M., 2009. Ventilation control of indoor transmission of airborne diseases in an urban community. *Indoor and Built Environment*, 18(3), pp.205-218.

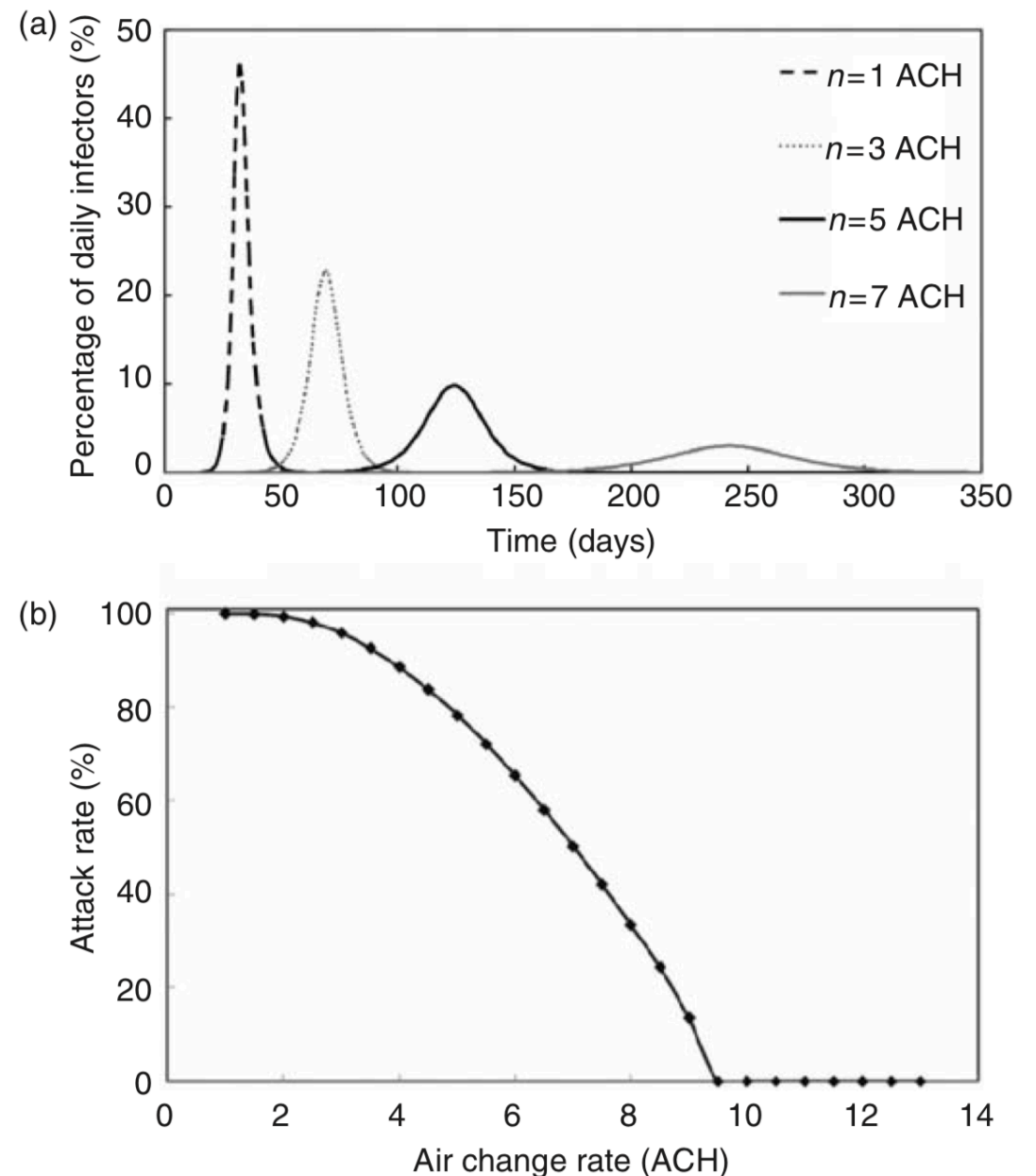


Fig. 2. The effect of increasing ventilation rate: (a) change of daily incidents, (b) change of overall attack rate.

What Ventilation Rate is needed?

	High Ventilation Dorm	Low Ventilation Dorm
CO2 concentrations in rooms	1230 ppm	1490 ppm
Dorm rooms' ventilation rates	6 L/s/person	2 L/s/person
Acute respiratory infections	2.1%	97.9%

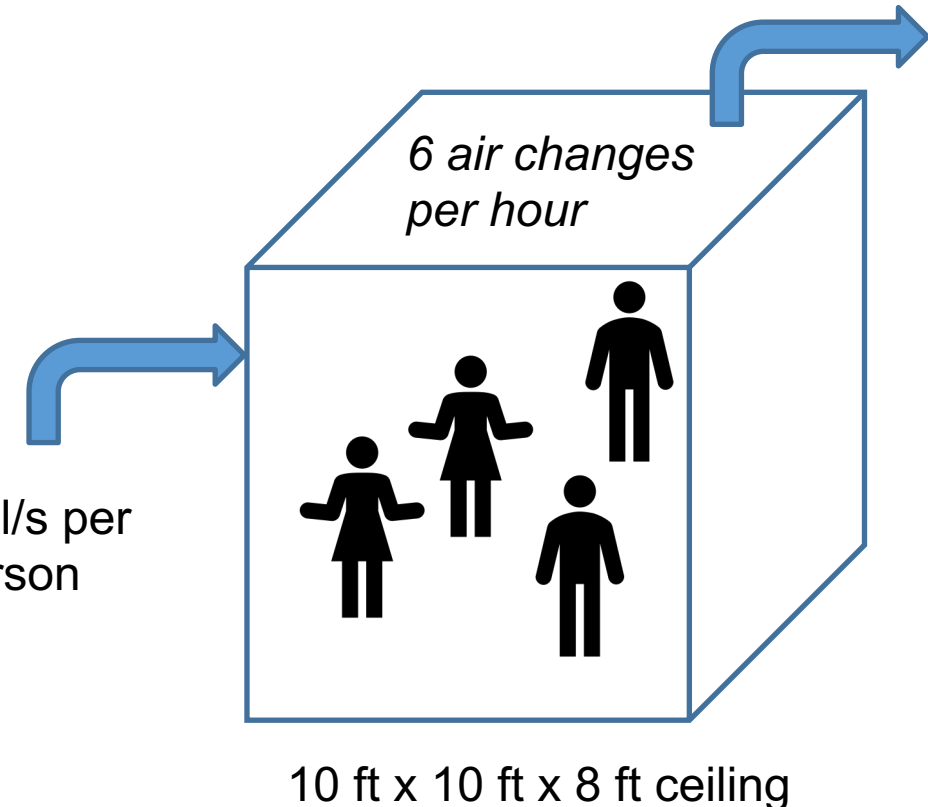
ventilation rates of **< 5 L/s per person** may be impacting acute respiratory infections

Zhu S, Jenkins S, Addo K, et al. Ventilation and laboratory confirmed acute respiratory infection (ARI) rates in college residence halls in College Park, Maryland. *Environment International*. 2020;137:105537. doi:[10.1016/j.envint.2020.105537](https://doi.org/10.1016/j.envint.2020.105537)

outdoor air supply rates **< 25 l/s per person** increase the risk of SBS symptoms, increase short-term sick leave, and decreased productivity

Wargocki P, Sundell J, Bischof W, et al. Ventilation and health in non-industrial indoor environments: report from a European Multidisciplinary Scientific Consensus Meeting (EUROVEN). *Indoor Air*. 2002;12(2):113-128. doi:[10.1034/j.1600-0668.2002.01145.x](https://doi.org/10.1034/j.1600-0668.2002.01145.x)

30 min will completely clear the room of contaminants at 6 ACH



Study Preliminary Results

Measurements at CU Boulder Air Quality Laboratory Testing Chamber



Phase I

- Flow visualization to understand the air flows that are released from wind instrument playing and singing
- Aerosol measurements within the major flows identified by the flow visualization
- Use CFD and published literature to explore mitigation question

Phase II

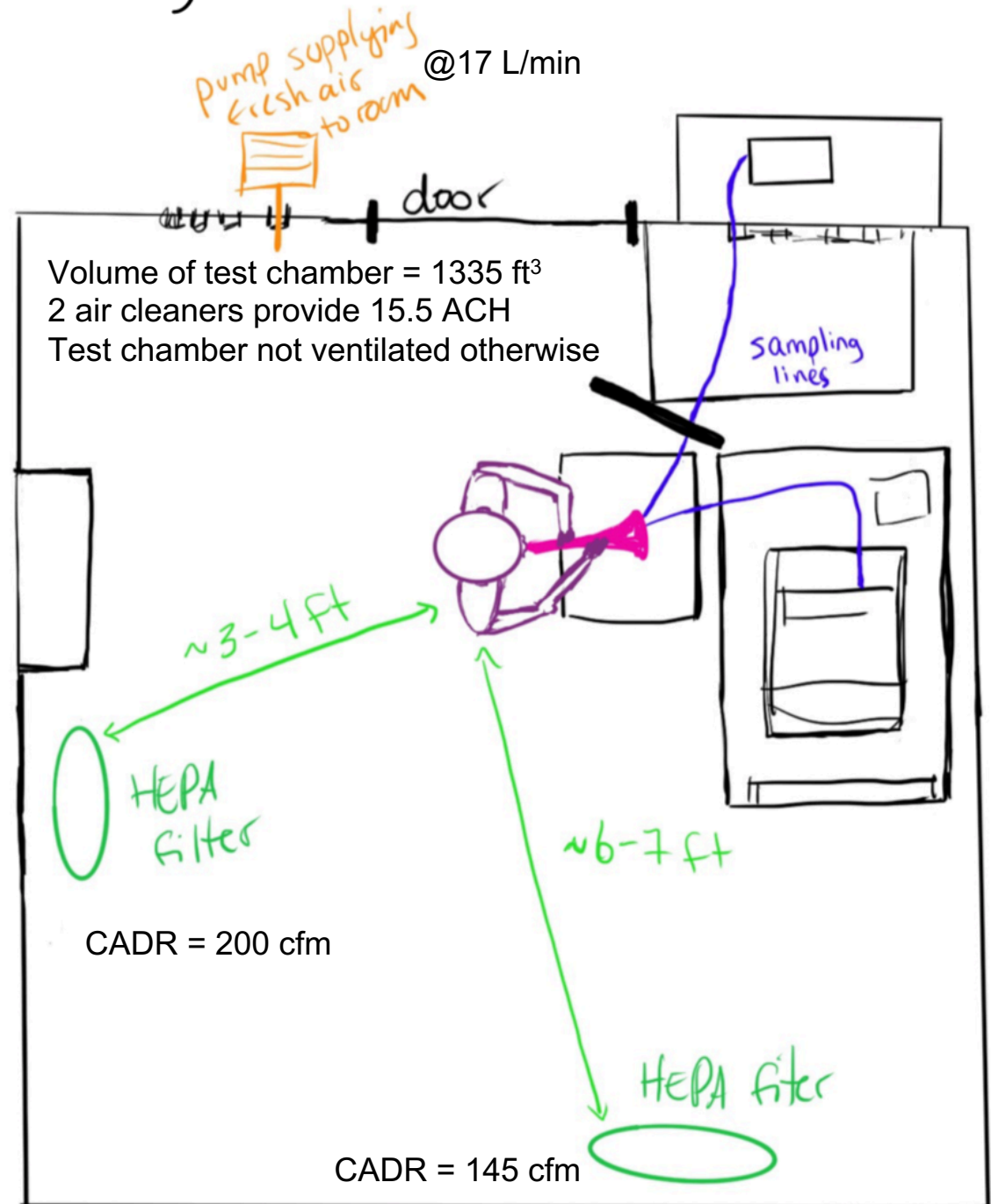
- Chamber studies to measure room aerosol concentrations from rehearsing with wind instruments

Phase III

- Small chamber measurements to assess emission rates (number of particles emitted per time)

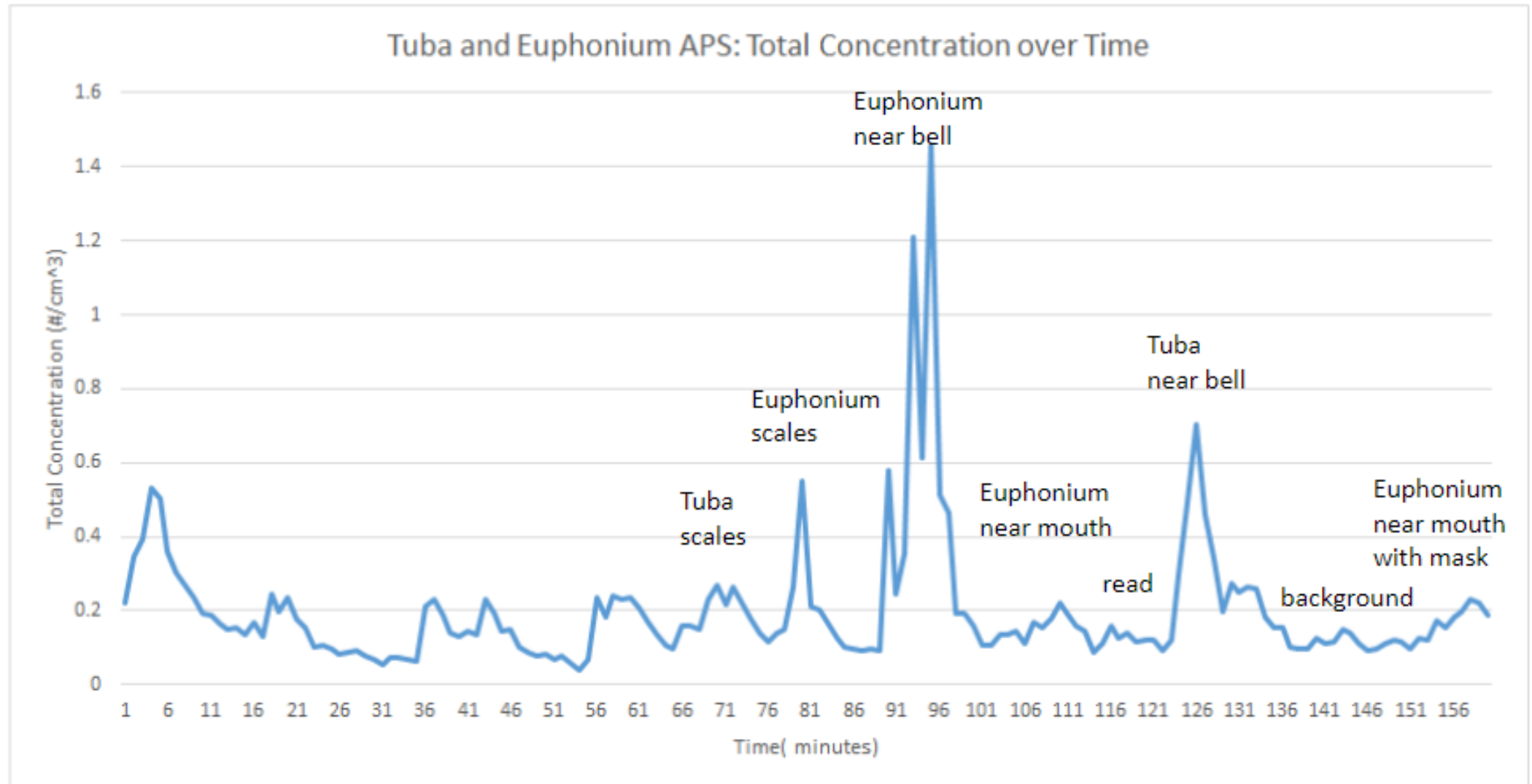
Phase IV

- Rehearsal room measurements at CU Boulder

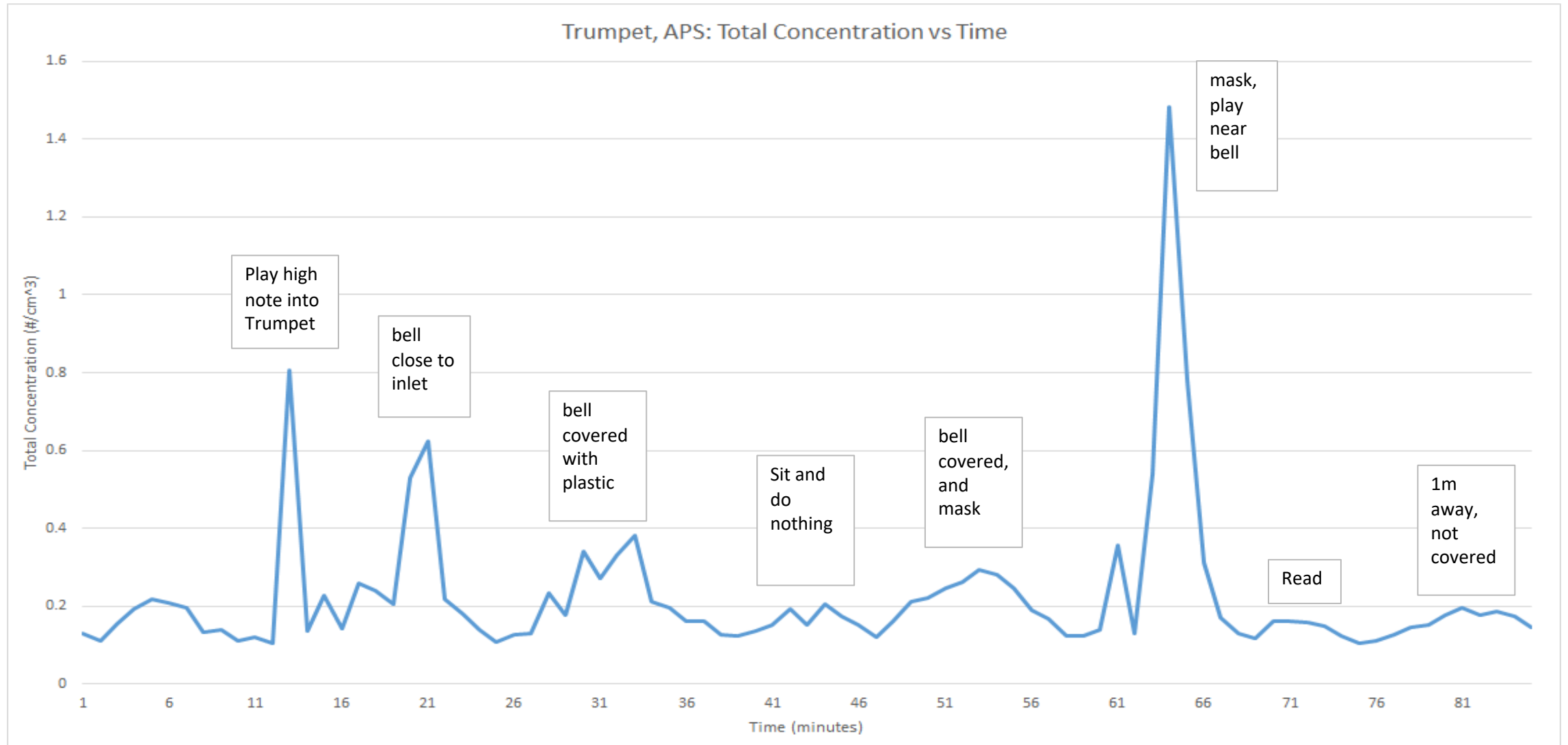


Low Brass

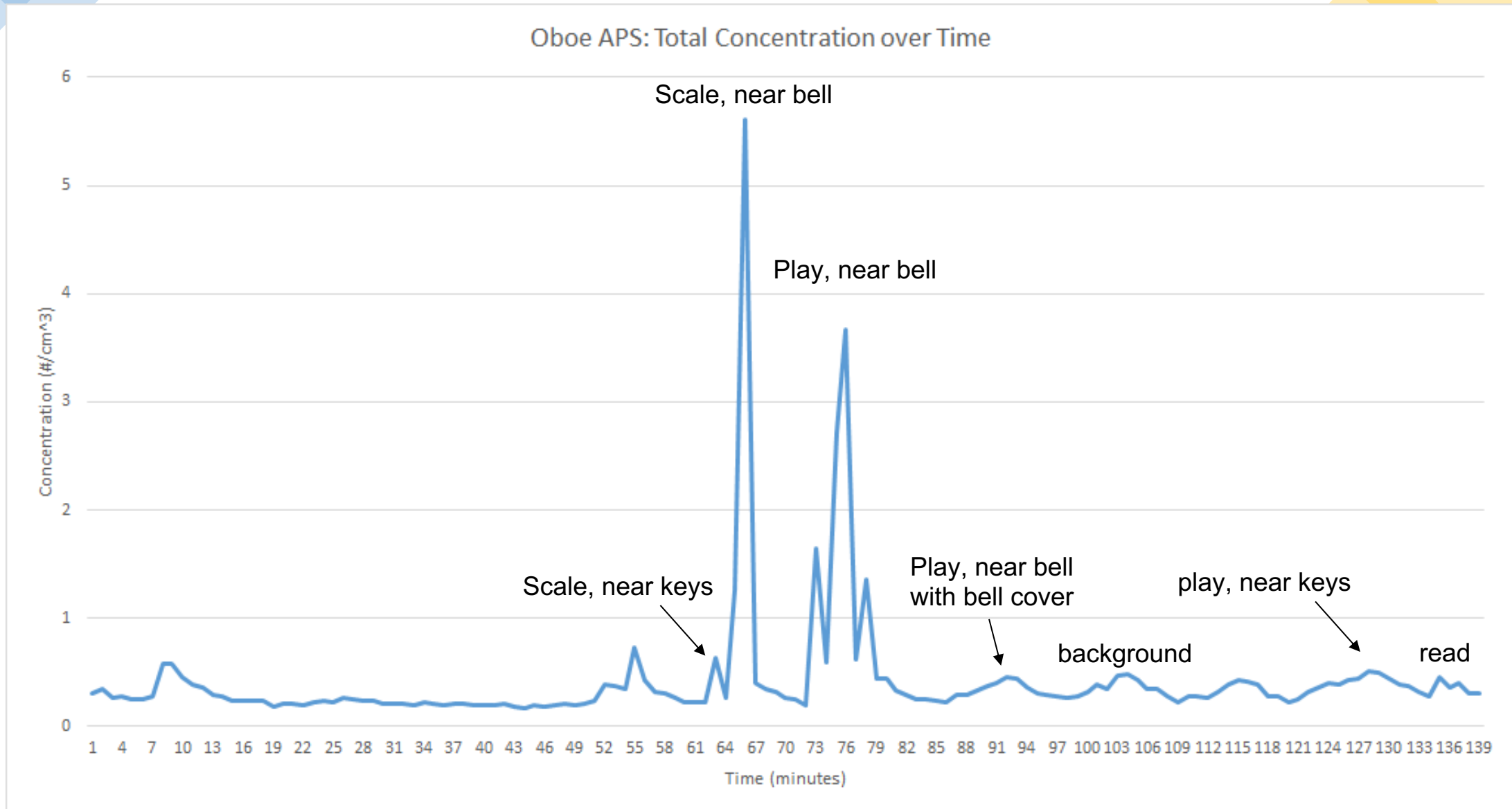
Particles sampled within the main flow plume
APS counts particles from 0.5 μm to $\sim 10 \mu\text{m}$ diameter



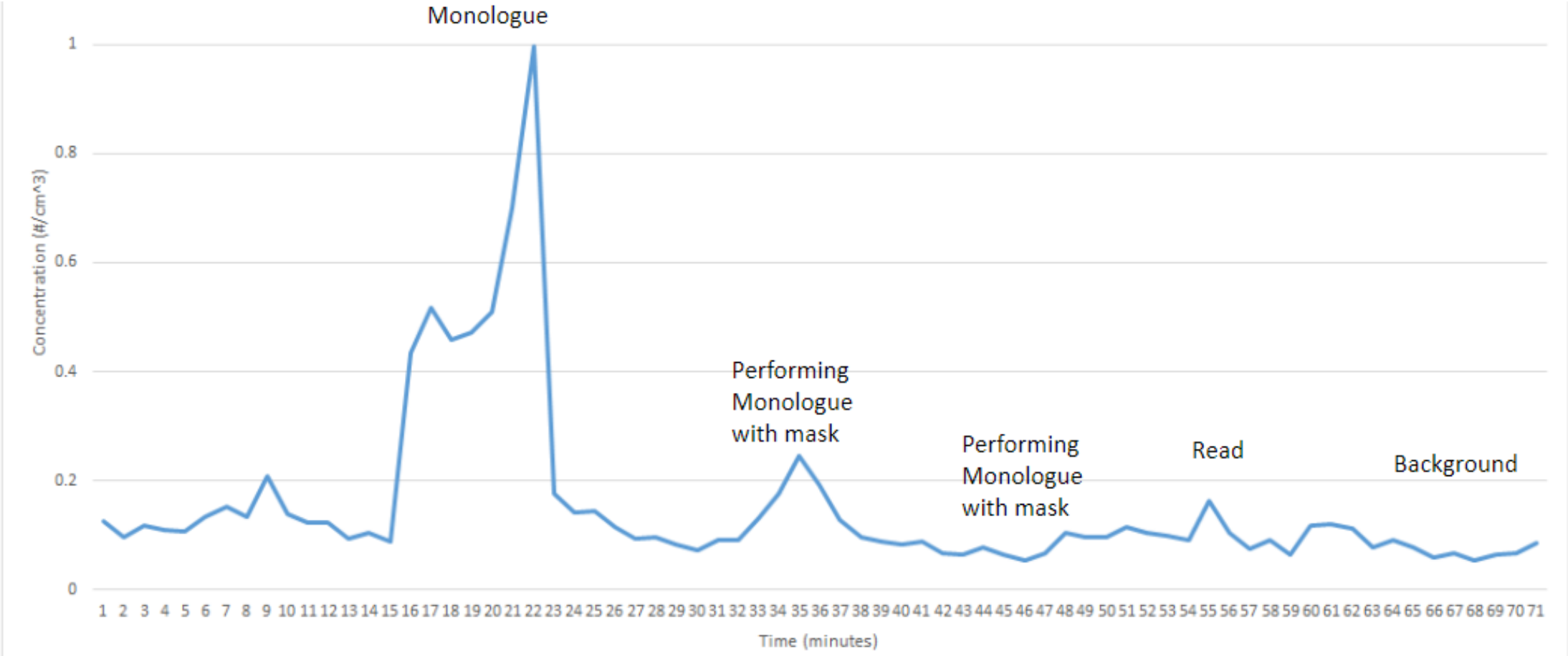
Trumpet



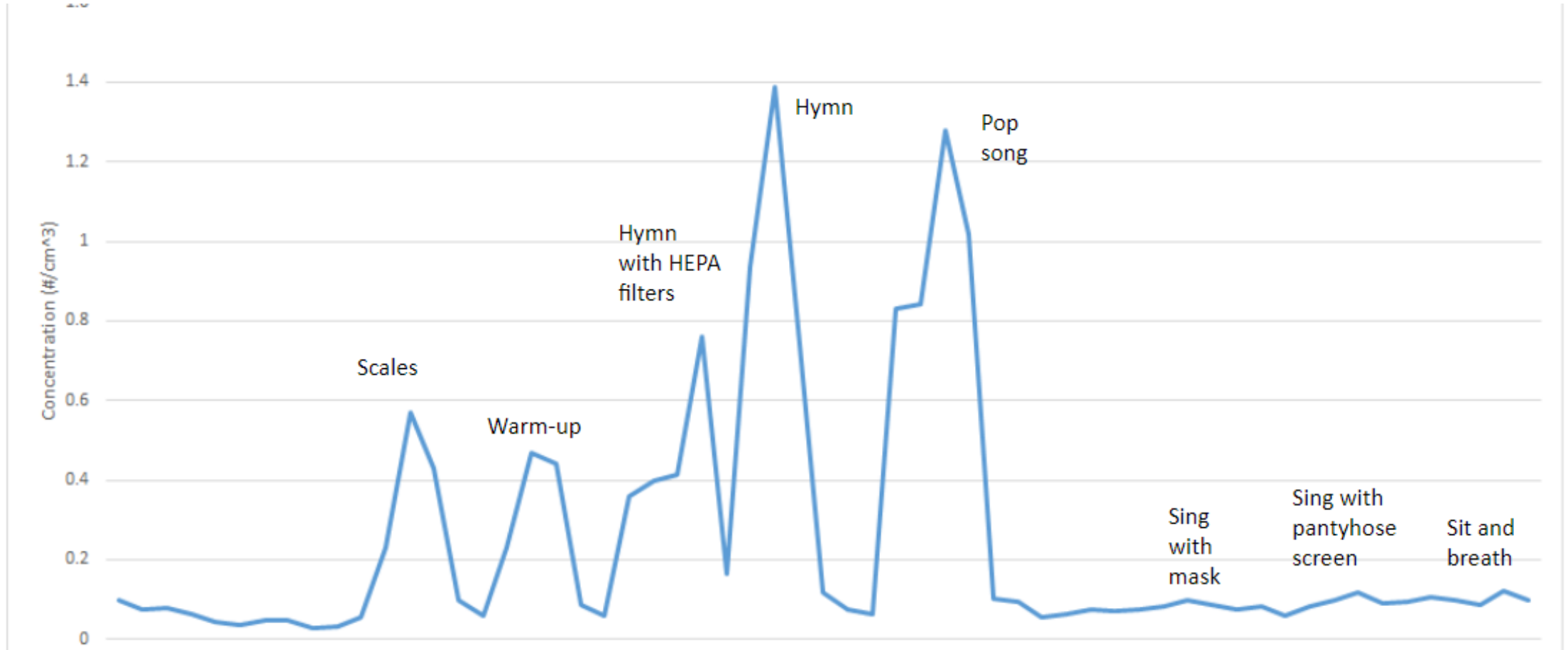
Oboe

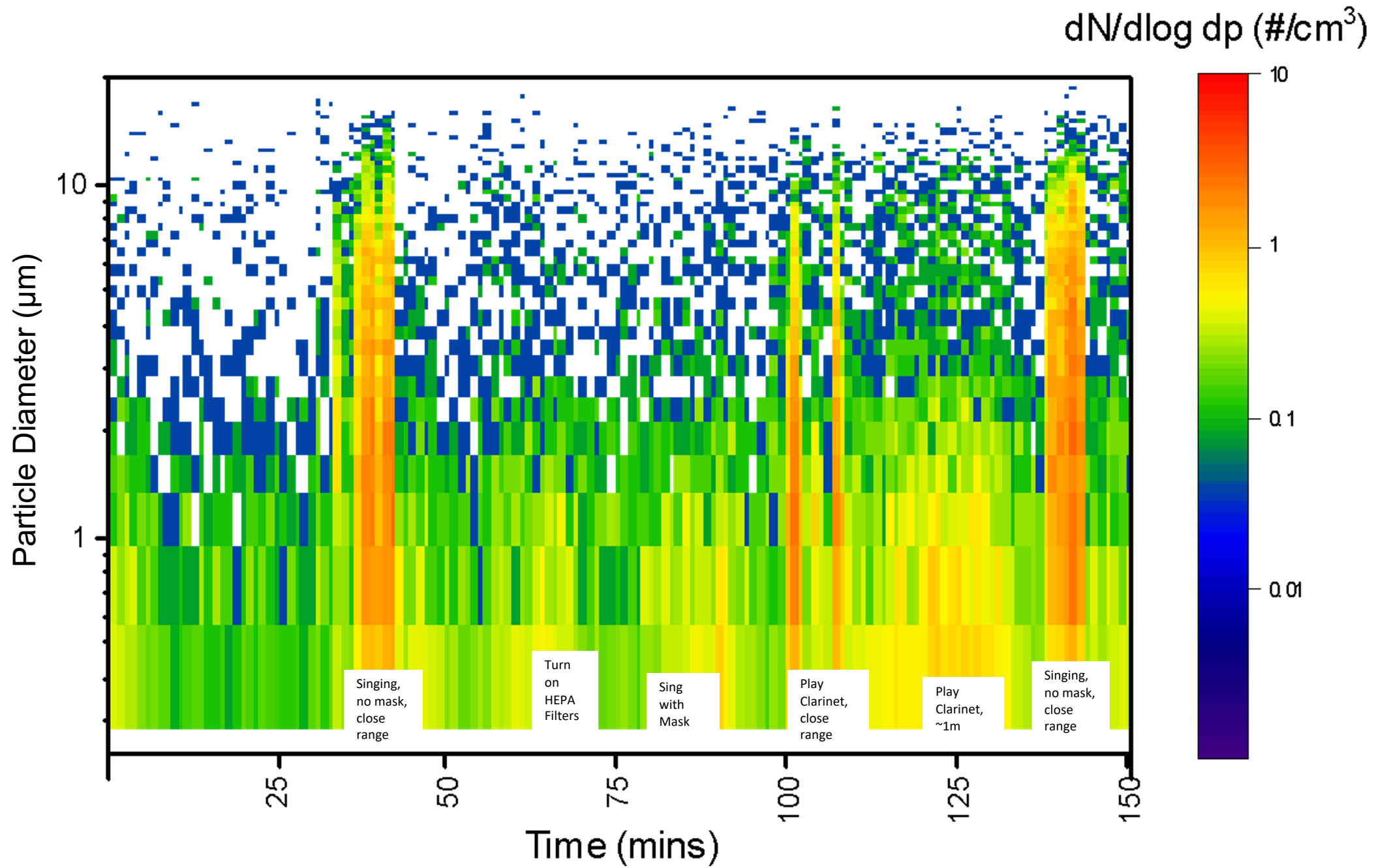


Theatre APS



Singing (APS)





Primary Aerosol Mitigation from Music Production: Schlieren Visualiz

July 2020, University of Colorado Boulder

Jean Hertzberg, Abhishek Kumar, Tehya Stockman

Other project personnel:

Shelly Miller, Marina Vance,
Darin Toohey, Sameer Patel

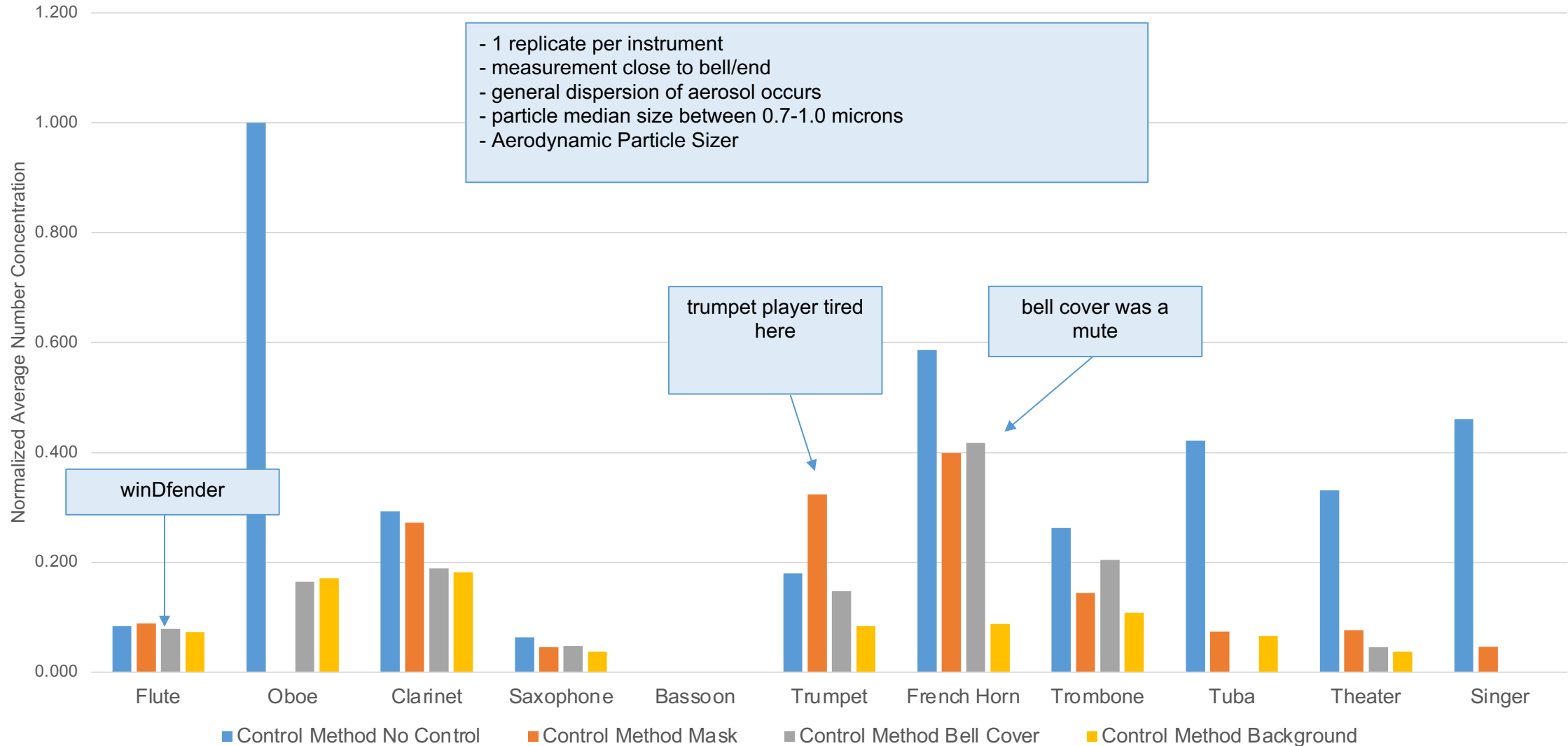
04:09



Prelim
Results:
[Video](#) (3 min)

Playing wind instruments releases airborne particles (aerosol). So does singing and projecting voice in theater performances. These particles are of the size range that transmits virus. Performing with mask and bell cover reduces emissions.

6- min average concentration normalized to max average



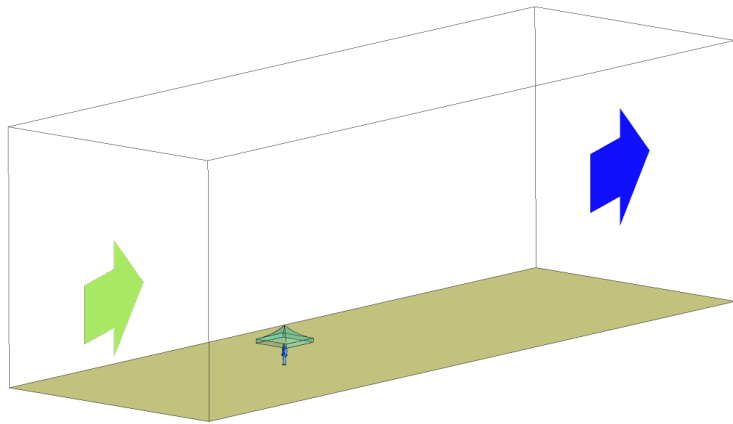
Computational Fluid Dynamics Modeling + Wells-Riley Infection Risk

- City@UMD team has analyzed the concentration of airborne COVID-19 particles in **one outdoor and two indoor case studies**
- **outdoor case study**
 - a musician in a light wind field of 1m/s (2.2 mph) at 10 m (33ft) above ground
- **Indoor Case 1**
 - both the supply and exhaust at the ceiling level, a typical ventilation system design
- **Indoor Case 2**
 - the supply at the ceiling and the exhaust at the floor

CFD Models

Outdoor Case (20 m × 60 m × 20 m)

Inlet (green arrow):
Vel.: 1 m/s at elevation of 10 m Temp.: 22°C
at elevation of 1.5 m

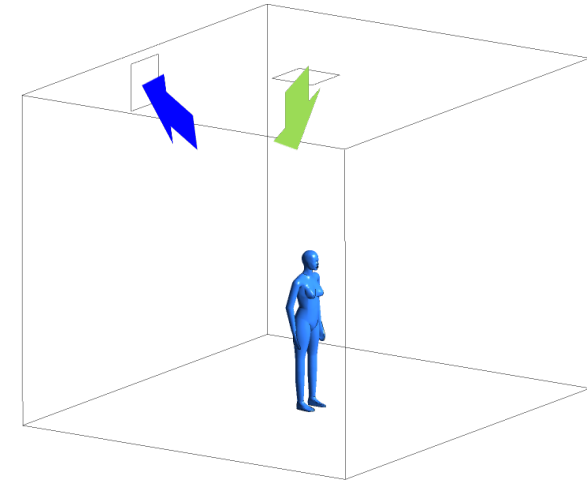


Outdoor Case



Indoor Cases (4.5 m × 4.0 m × 3.5 m)

Inlet (green arrow):
Size: 0.5 m × 0.5 m
Vel: 0.21 m/s (3 ACH)
Temp.: 22°C



Indoor Case

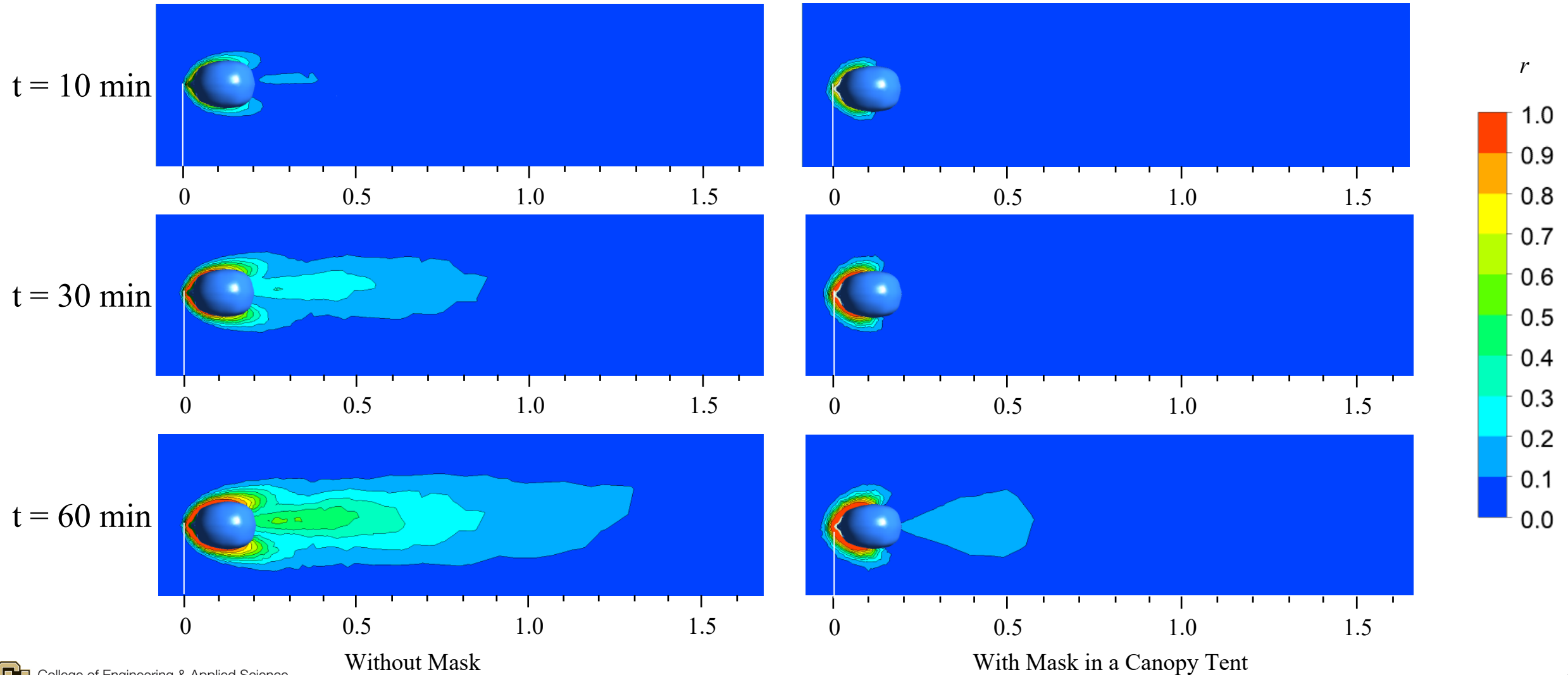
Human Body: Area of 1.47 m² and Heat flux of 23 W/m²

Mask: Area of 107.7 cm², Velocity of 0.02 m/s (mass flow rate same as the exhaled air of the singer), and Temp. of 32°C

Covid-19 generation rate: 17.28 quant/hr with a 64% particle removal efficiency

Outdoor Case: Impact of Tent/Masks on Infection Risk

Infection risk r by Wells-Riley equation at the height of mouth opening, with breathing rate of 8 L/min.

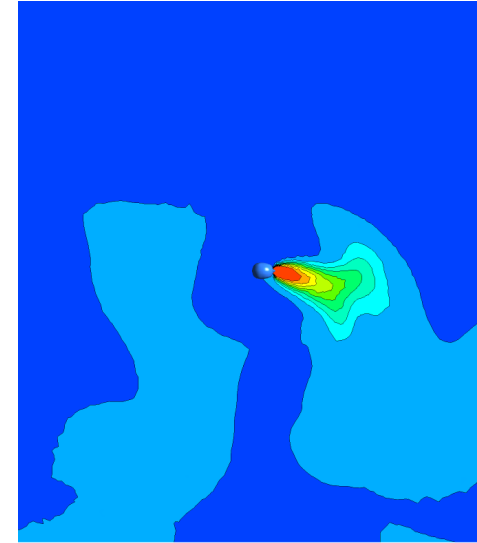
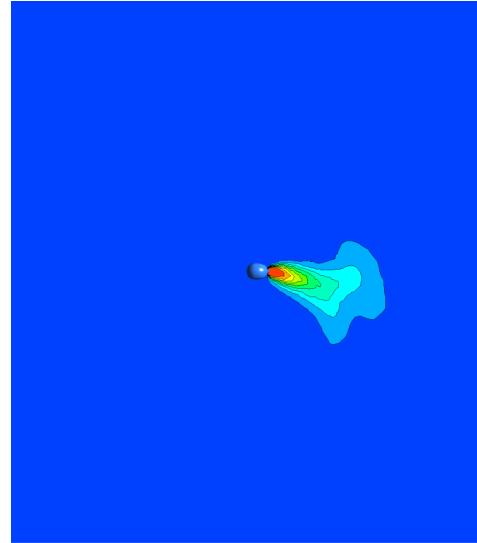
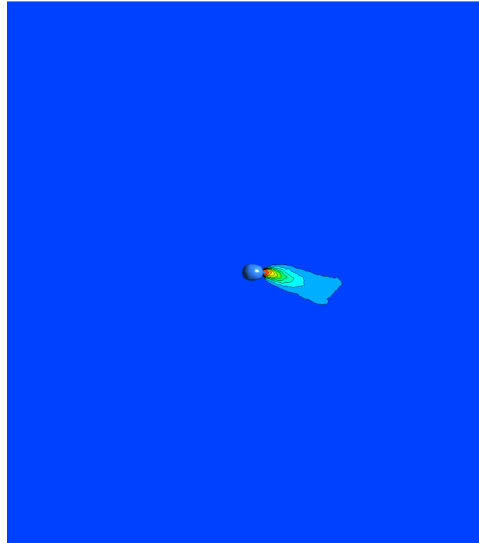


Indoor Case: Mask Impact on Infection Risk

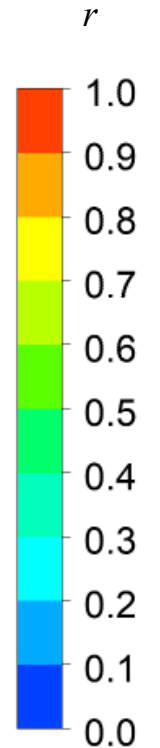
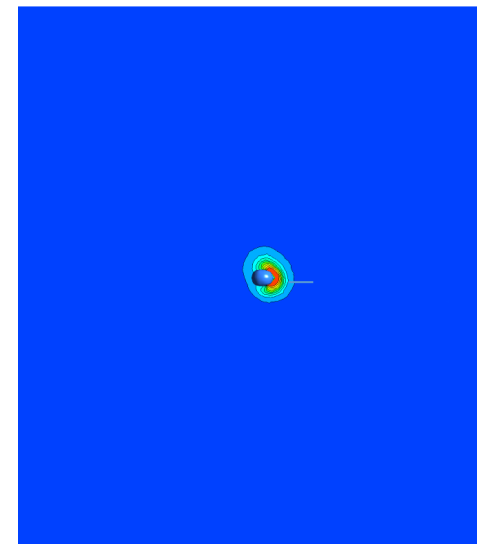
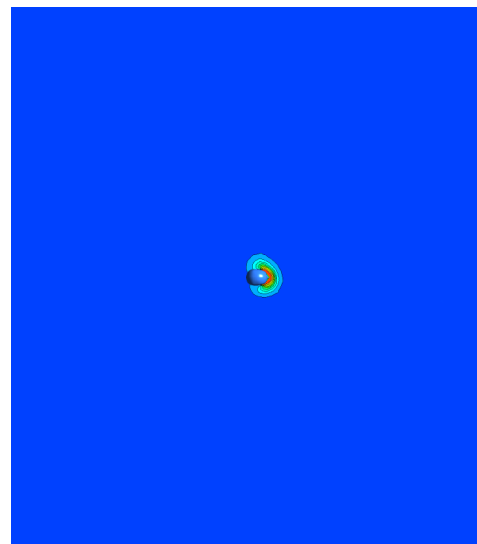
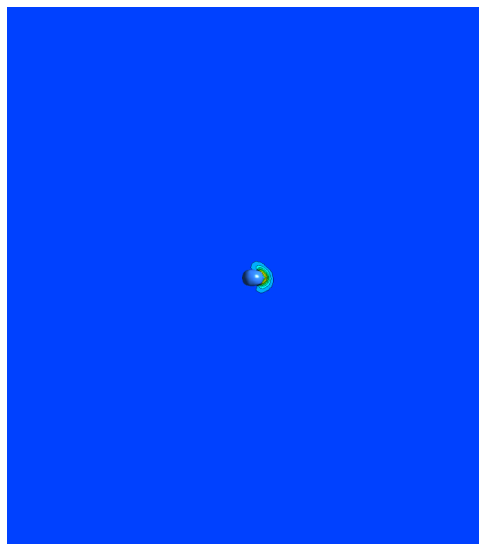
Infection risk r by Wells-Riley equation at the height of mouth opening, with breathing rate of 8 L/min.

Floor size:
4 m × 4.5 m

Singing
without mask



Mask with 64%
efficiency

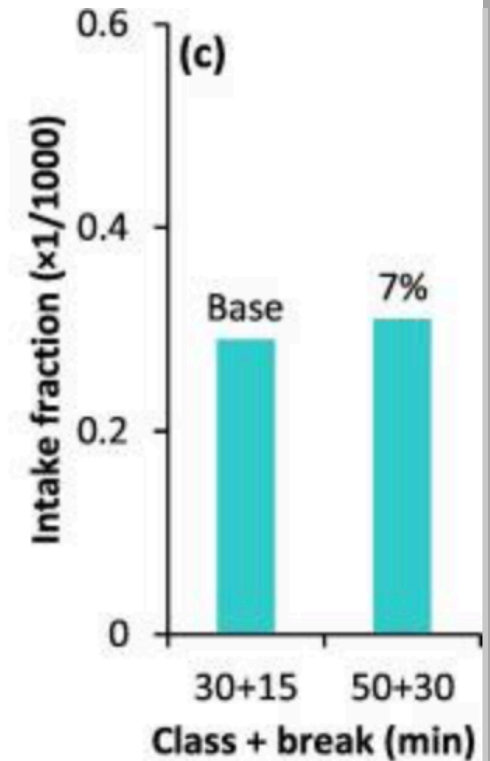
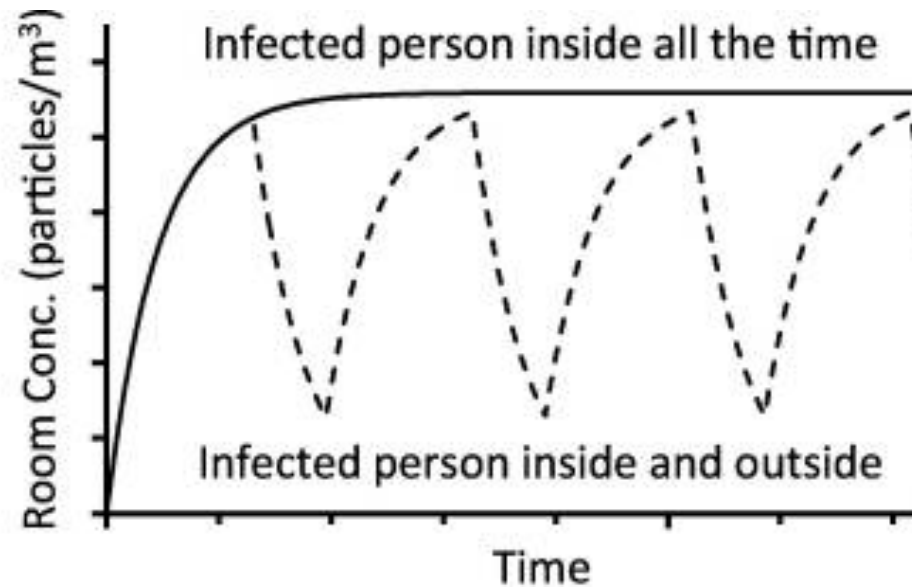
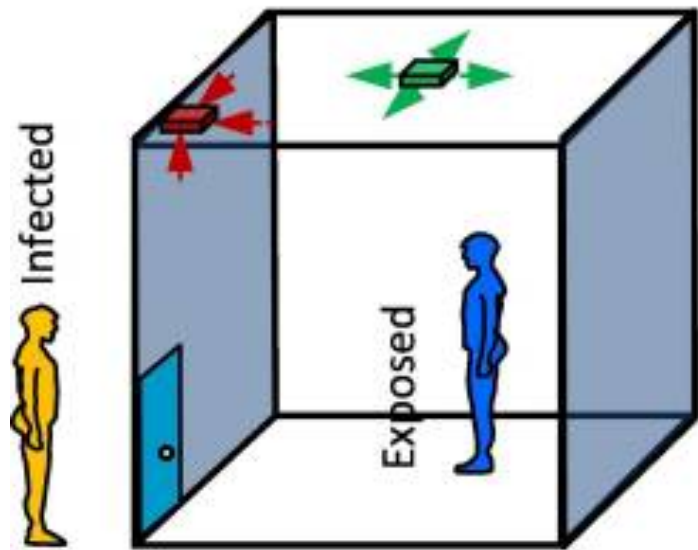


$t = 10$ min

$t = 30$ min

$t = 60$ min

One of our recommendations is to rehearse indoors for 30 min and take breaks equivalent to 1 air change, 3 would be best



Melikov AK, Ai ZT, Markov DG. Intermittent occupancy combined with ventilation: An efficient strategy for the reduction of airborne transmission indoors. *Sci Total Environ.* 2020;744:140908.

5 lessons of 30 min, 4 15 min breaks
3 lessons of 50 min, 2 30 min breaks

Preliminary Evidence-based airborne infectious disease controls musicians/singers

Masking for Wind Instruments



Wear well-fitting efficient masks to play and sing

Play with efficient bell/end covers reducing source dispersion

Spatially distance 6 ft (9x6 for trombone)

- Reduce viral loading, unsuspected transmission, social distance to get out of aerosol plume

Minimize indoor time to 30 min, with breaks

Increase outdoor air ventilation rates and distribute effectively

- Do not use partitions, disrupts flow patterns

Use air cleaning if minimal ventilation rate

- if 3 ACH, add additional 3 ACH with air cleaning

Wash hands and surfaces with soap, alcohol-based sanitizer

Outdoors is best, tents with no sides ok

Avoid the "Three Cs"!



Closed spaces
with poor ventilation

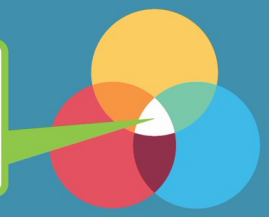


Crowded places
with many people nearby



Close-contact settings
such as close-range conversation

The risk of COVID-19 clusters is particularly high when the "Three Cs" overlap.



In addition to the "Three Cs":



Wear your mask to protect yourself and those around you.



Clean items used by multiple people with disinfectant.



Wash your hands with soap and water for at least 20 seconds.



Stay home if you are sick or have symptoms!

Visit [FloridaHealth.gov](https://www.floridahealth.gov) for additional information.

Huge thanks to our research team, our study chairs, sponsors, scientific colleagues, music educators, performers, players, students...



Additional study information can
be found here:

<https://www.nfhs.org/>