Bioaerosol Emissions and Exposures in the Performing Arts: A Scientific Roadmap for a Safer Return from COVID19

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Why don’t we have more answers here?

• For every 1,000 doctors that graduate from US medical schools, we see ~1 new PhD granted in aerosol science

• There are probably fewer than 5,000 aerosol PhDs actively working in the U.S.

• 80% of those PhDs work outside of academia

• Probably less than 5% study bioaerosols and public health

• Not everything you read on the internet is true…
Questions we hope to answer

1. What is the rate (and size) of bioaerosol emitted by performers of varying age and gender when engaging in music, voice, and dance?

2. How effective are active and passive control measures at reducing bioaerosol emissions and exposures?
   - isolation and distancing
   - room ventilation and filtration
   - use of homemade masks, respirators, shields or other barriers

3. Can the risks of co-exposure be reduced to “acceptable levels” using these active and passive controls?
Some Sizes and Sources of Airborne Particles

Particle Size, $\mu$m
Some Sizes and Sources of Airborne Particles

Flour Dust

Particle Size, µm
Some Sizes and Sources of Airborne Particles

Pollen

Particle Size, µm
Some Sizes and Sources of Airborne Particles

Particle Size, µm

Spray
Some Sizes and Sources of Airborne Particles

Smoke

Particle Size, $\mu m$
Some Sizes and Sources of Airborne Particles.
Some Sizes and Sources of Airborne Particles

- Breathing
- Sneezing & Coughing
- Talking
- Musical and Vocal Arts?

Particle Size, µm

0.1 1 10 100
Human bioaerosol spans a huge size range (and not all particles behave the same)

- If this particle were the size of a baseball
- Then this particle would be the size of a baseball stadium
CSU Mask and Respirator Testing Program

- Shortage of N95 respirators for healthcare workers across Colorado
- Supply of domestic and international respirators of unknown quality / performance
- On March 25th, Colorado Governor Jared Polis asked our lab to provide respirator testing & performance verification for State of Colorado COVID-19 Task Force

Over 200 different mask designs tested as of 20 Aug 20
N95 means 95% removal efficiency for particles that flow into the mask.

CSU testing program follows modified* NIOSH protocol for particle collection and “breathability”

“Looks” can be deceiving!

Only CDC/NIOSH can certify masks to bear the “N95” label.

* [https://www.cdc.gov/niosh/npptl/respirators/testing/default.html](https://www.cdc.gov/niosh/npptl/respirators/testing/default.html)
Anonymous Donor:

“Please test these 24 different masks, each made with popular mask material, and make the data publicly available”
Most N95 masks remove ~99% of all particle sizes.
Size Range of Concern for COVID19, via WHO →

Range of Concern for Aerosol

← Research Community Studying COVID19

WHO →

Fraction Collected by Mask vs. Particle Size, µm

mask

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Mask4: 2-ply high thread-count cotton
Mask17: Add a MERV13 filter layer to Mask4

Mask4: 2-ply high thread-count cotton

Fraction Collected by Mask

Particle Size, μm

Nordic Pure AC & FURNACE AIR FILTERS

mask

4

17
Mask17: Add a MERV13 filter layer to Mask4

Mask18: Wash that fancy mask 3 times

Mask4: 2-ply high thread-count cotton
What about “Singer’s Masks”? 
Every singer’s mask tested to date has performed poorly, according to our standards.
Reducing Bioaerosol Emissions and Exposures in the Performing Arts: A Scientific Roadmap for a Safer Return from COVID19
Experimental Design

• 100 volunteers over 3 months (~2/day)
  • Open to ages 12 and up; all genders
  • ~28 singers, actors, dancers
  • ~72 instrumentalists: bassoon, clarinet, euphonium, flute, French horn, trumpet, trombone, saxophone, and possibly others

• Everybody speaks, sings and “does their thing”
  • With and without control technologies in place
    • Masks, bell covers, and screens to be tested
    • “BYOM” approach to testing

• Particle sizes from 0.01 to 100 micrometers
SET Facility: A Musical Class 100 Cleanroom
SET Facility: A Musical Class 100 Cleanroom
Preliminary Instrument Results (particles > 0.3 µm)

Particle Emissions

- highest
- higher
- lower
- very low

Instruments:
- bassoon
- flute
- french horn
- oboe
- piccolo
- saxophone
- trumpet
Preliminary Vocal Results

(particles > 0.3 \( \mu \text{m} \); \( n = 9 \) participants; colors represent different individuals)
Preliminary Findings (less than 1/5\textsuperscript{th} of the way there)

1. Wind instruments produce aerosol of varied concentration and size

   \textit{higher levels} \quad \textit{intermediate} \quad \textit{very low}

   Trumpet, saxophone, bassoon $>$ French horn, oboe, voice $>$ flute, piccolo

2. Masks reduce vocal emissions by 90\% or more

3. Variability from one person to the next is IMPORTANT.
Thank you to those who made this work possible!

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