Use of Portable Air Cleaners to Help Minimize Potential for Indoor Transmission of SARS-CoV-2

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3Flow - 25 years of working with clients committed to safe, efficient and sustainable facilities

- Universities
- Government
- Chemical
- Biotechnology
- Pharmaceutical
- Industry
Are you safe indoors?
How do you know?

What defines success?

- Understand Risk and Areas of Concern
- Provide indoor spaces that are safe and productive
- Minimize waste and resource expenditure
- Maximize sustainability and resilience
- Confidence that people can be safe indoors together

Strive to manage risk to as low as reasonably achievable
Research labs and critical workspaces are specially designed to protect people working with airborne hazards.

Biosafety Level 3 Lab (BSL-3) would be warranted for work with SARS-CoV-2.
Most indoor spaces are simply not designed to protect people from exposure to airborne pathogens

In addition, infected people are mobile emission sources ... and we don’t know who they are!
Is my building safe?

Offices

Conference Room

Training Center

Break Area

Warehouses

Lab and Support Spaces

What is good ventilation?

Exhaust/Return

Air Supply

Many different spaces with different design and operating requirements

Waiting Areas & Meeting Rooms

Special Process Areas

Offices

Labs & Critical Workspaces

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Primary exposure occurs in the communal air space

Are you downwind?

Infectious DOSE = Concentration x Duration

Infectious People can emit more than 40,000 particles every 15 minutes

Infectious Dose for Influenza approximately 1900 – 3000 viable particles.

Infectious Dose for Coronavirus is currently unknown.

The effectiveness of masks may be controversial, but limiting generation can reduce risk

Reduced Generation?

Concentration = Generation / Air Flow
Is the ventilation system helping to mitigate risk?

**Concentrations accumulate during generation and reduce when generation stops. Dose is the total exposure.**

- Generation Starts (i.e. Infected Person Enters Space)
- Generation Stops (i.e. Infected Person Leaves)
- Accumulation
- Dilution / Removal

Concentrations accumulate during generation and reduce when generation stops. Dose is the total exposure.
Many spaces are not well-mixed. Is this bad?

Sweep and Remove

Airflow Patterns Matter – Are you downwind?
Airflow Patterns Matter - Rooms may not be well mixed

Can you say Super Spreader?
**Investigate and Reduce Risk of Indoor Transmission**

- **Step 1 – Evaluate Risk and Demand for Ventilation**
  - Gather building documentation
  - Conduct Risk Assessment
  - Identify Spaces of Concern

- **Step 2 – Inspect and Measure HVAC Operation**
  - Air Handling and Return Air Units Operational
  - Measure Flow and Calculate Air Change Rates

- **Step 3 – Select and Implement Safety Measures**
  - Upgrade HVAC Systems
  - Implement Portable Air Cleaners

- **Step 4 – Verify and Maintain Proper Operation**
  - Measure concentration accumulation, dispersion and decay
  - Confirm and maintain Ventilation Effectiveness

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**A Risk Assessment can identify spaces of concern and prioritize efforts to improve safety**

<table>
<thead>
<tr>
<th>Risk Band</th>
<th>Description</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Negligible</td>
<td>• Vacant Space</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• ≤ 1 Occupant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Very Limited Access</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Proper HVAC Operation</td>
</tr>
<tr>
<td>1</td>
<td>Low</td>
<td>• ≤ 1 Known Occupant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Limited to no Visitors</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Proper HVAC Operation</td>
</tr>
<tr>
<td>2</td>
<td>Moderate</td>
<td>• Known Occupants</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Limited Visitors w/Short Duration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Adequate Spacing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Proper HVAC Operation</td>
</tr>
<tr>
<td>3</td>
<td>High</td>
<td>• Known Occupants</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Limited Visitors w/ Extended Duration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Mixed Social Space and Close Contact</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ventilation Issues</td>
</tr>
<tr>
<td>4</td>
<td>Extreme (Special)</td>
<td>• Known Occupants</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Numerous, Frequent Visitors w/Extended Duration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Close Personal Contact</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Aerosol Generating Procedures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ventilation Issues</td>
</tr>
</tbody>
</table>

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Areas of concern were identified to determine the need for special safety measures

<table>
<thead>
<tr>
<th>Risk Scale:</th>
<th></th>
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<tbody>
<tr>
<td>0</td>
<td>Negligible</td>
</tr>
<tr>
<td>1</td>
<td>Low</td>
</tr>
<tr>
<td>2</td>
<td>Moderate</td>
</tr>
<tr>
<td>3</td>
<td>High</td>
</tr>
<tr>
<td>4</td>
<td>Extreme/Special</td>
</tr>
</tbody>
</table>

Out of 28 spaces, only 5 may require special measures
Inspect and Measure HVAC Operation

Training Center
Area (A) = 704 ft²
Height (H) = 10 ft
Volume (V) = 7,040 ft³
Supply (Qs) – 536 cfm
Exhaust (Qex) – 540 cfm
Temp – 69 °F, RH - 46%

Air Change Rate

\[ ACH = \frac{Q}{V} \]

Air Changes per Hour (ACH) = \[ \frac{540 \text{ ft}^3/\text{min}}{7,040 \text{ ft}^3} \times 60 \text{ min/hr} \]

ACH = 4.6

Ventilation Effectiveness can be measured

- Air Tracer Generation (G) (IPA and Particulates)
- Detectors Located at S1-S6 (PIDs, Particle Counters)

Generate Tracer

Sample Tracer

Quadrant 1

Far Field Exposure

S1

G

S5

Near Field Exposure

S4

S3

Quadrant 2

Quadrant 3

Interzonal Migration

S6

Quadrant 4

Generate Tracer

Sample Tracer

Good

Okay

Bad
VEFF Tests use Air Tracers to challenge and quantify Ventilation Effectiveness

A Theoretical Well-Mixed Space would yield instantaneous and homogeneous concentration profile at all locations
Air tracer tests indicate different results from well-mixed performance

VEFF Test Results for Training Center operating at 4.6 ACH

Ventilation Effectiveness is 3.5 times worse than Theoretical Well-Mixed Case

VEFF Ratio: 3.5
The risk and ventilation effectiveness may justify the need for additional safety measures such as Portable Air Cleaners

- **VEFF ≤ 1**
  - Well-Mixed
  - Good Sweep and Removal
  - Okay with Adequate Flow

- **VEFF > 1**
  - Short Circuiting
  - Supply Only, No Exhaust
  - Consider HVAC Modifications or Portable Air Purifiers

- **VEFF >> 1**
  - Exhaust Only, No Supply
  - No Supply or Exhaust
Consider special safety measures and use of Portable Air Cleaners

- What are Air Cleaners and HVAC Filters
- Steps to Select Portable Air Cleaners
- Evaluate Type of Ventilation System
  - Mechanical vs Natural Ventilation
- Guidance on Selection
  - Preference for Filtered Units
  - Filter types and Removal Efficiency
  - Evaluate room and size unit (CADR)
  - Consider number and location of units
  - Consider Cost, Maintenance and Noise
Portable Air Cleaners should include internal fans and filters

- CADR 100-400 cfm
- Charcoal Pre-filter
- HEPA filter

Floor Unit

Velocity
500 - 1000 fpm

99.9% Capture Effectiveness

Inlet

Outlet

Consider space size and configuration to select type, size and quantity of Portable Air Cleaners

- Consider the size and configuration of the space
- Large spaces may require multiple units
- Consider supply and exhaust locations
- High Ceilings and unique room configurations may require special solutions

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Consider Location of Portable Air Cleaners

- Room Size and Configuration
- Portable Air Filter Size and CADR
- Placement and Impact on Airflow Patterns

1 – Ceiling Mounted

2 – Side Wall Mounted

3 – Floor Mounted

Consider placement of portable air purifiers to maximize dilution and removal of contaminants
High ceilings may pose problems for portable air cleaners

Mixing and removal may be compromised

Other techniques such as UVGI may be applicable

Consider Air Purifier Noise Levels

Unit OFF

Unit ON – LOW

Unit ON - HIGH

40 dB – Quite Library
60 dB – Conversation
80 dB – Loud Music

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Portable Air Cleaners were installed in the Training Center.

The Portable Air Cleaners reduced exposure dose.

VEFF Test – Generation at Mannequin A

Dose Reduced by 39%
VEFF Tests – the portable air filters reduced exposure dose

**VEFF Test – Filters OFF**

Pots of Particle Counts for 0.3 um - No Filters

**VEFF Test – Filters ON**

Pots of Particle Counts for 0.3 um - with Filters

71% Reduction of 0.3 µm Particles

The Portable Air Cleaners improved ventilation effectiveness

**Filters OFF**

**Filters ON**

Filters Yield 42% Dose Reduction

<table>
<thead>
<tr>
<th>Avg. Dose</th>
<th>Theoretical Dose</th>
<th>VEFF Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1-S5</td>
<td>4.45</td>
<td>3.5</td>
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<tr>
<td></td>
<td>1.28</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Avg. Dose</th>
<th>Theoretical Dose</th>
<th>VEFF Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1-S5</td>
<td>2.60</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>1.27</td>
<td></td>
</tr>
</tbody>
</table>
Consider the Sources, Pathways, and Receptors

![Diagram showing source, pathway, and receptors](image)

Implement Safety Measures and Manage Risk

- Discourage infected people from entering the building
- Implement a Ventilation Management Program (Coordinate and Communicate)

<table>
<thead>
<tr>
<th>Item</th>
<th>Prudent Measures to Reduce Risk</th>
<th>Risk Level</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>Administrative Controls</td>
<td>X</td>
</tr>
<tr>
<td>2</td>
<td>Wear Masks and Respirators</td>
<td>X</td>
</tr>
<tr>
<td>3</td>
<td>Distancing and Physical Isolation (where possible)</td>
<td>X</td>
</tr>
<tr>
<td>4</td>
<td>Test and Verify HVAC Function</td>
<td>X</td>
</tr>
<tr>
<td>5</td>
<td>Consider Airflow Modifications (e.g. Supply / Exhaust)</td>
<td>X</td>
</tr>
<tr>
<td>6</td>
<td>Consider Special In-Room Measures (e.g. Portable Air Purifiers)</td>
<td>X</td>
</tr>
<tr>
<td>7</td>
<td>Utilize Appropriate Personal Protective Equipment</td>
<td>X</td>
</tr>
<tr>
<td>8</td>
<td>Consider Installation of System Filtration</td>
<td>X</td>
</tr>
<tr>
<td>9</td>
<td>Consider Installing System Bio deactivation (e.g. UVGI)</td>
<td>X</td>
</tr>
<tr>
<td>10</td>
<td>Test and Verify Performance of Safety Measures</td>
<td>X</td>
</tr>
</tbody>
</table>
Implement a Ventilation Management Program

- Gather Building and Space Information
- Conduct Space Risk Assessment
  - Evaluate Space Utilization
    - Types of Occupants
    - Occupant Density
    - Occupant Duration
  - Evaluate HVAC Operation
- Implement Administrative Plans
- Implement Applicable Safety Measures
- Test and Verify Performance
- Train Personnel and Manage Operation

Conclusions and Recommendations

- The risk of exposure and transmission of Covid-19 indoors can be managed with implementation of a multifaceted plan
- Spaces can be evaluated to determine relative risk
- Not all spaces will require change and use of special measures
- Tests and modeling can be applied to evaluate the effectiveness of the systems to dilute and remove hazards
- Portable Air Purifiers can be used to enhance occupant protection
- Coordination, communication and training of key stakeholders and building occupants is critical to success
- Implement a Ventilation Management Program

Plan • Assess • Optimize • Manage
Thank You!

Stay Safe – Stay Upwind

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