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

Thomas C. Smith
President / CEO
tcsmith@3flow.com
www.3flow.com
919-319-4290

Copyright © 2021

1

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

- Universities
- Government
- Chemical
- Biotechnology
- Pharmaceutical
- Industry

Copyright © 2021

2

3

What defines success?

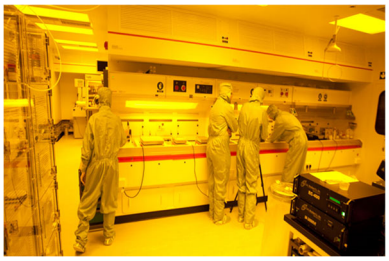
- Understand Risk and Areas of Concern
- Provide indoor spaces that are safe and productive
- Minimize waste and resource expenditure
- Maximize sustainability and resilience
- Confidence that people can be safe indoors together

Strive to manage risk to as low as reasonably achievable

Copyright © 2021

4

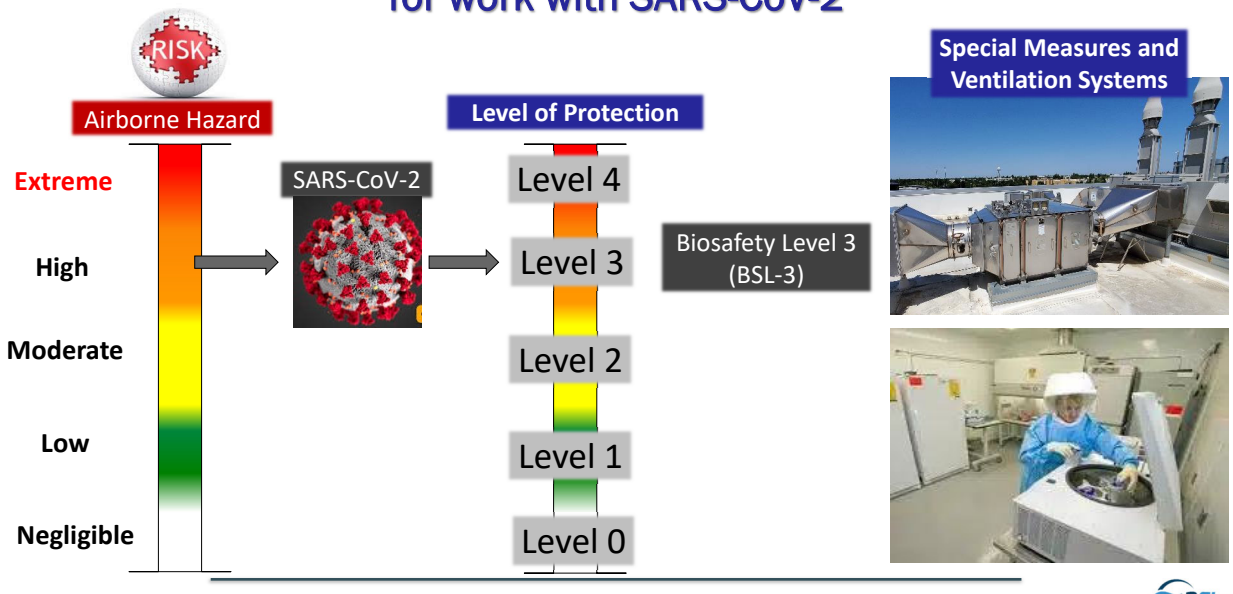
Research labs and critical workspaces are specially designed to protect people working with airborne hazards



Copyright © 2021

5

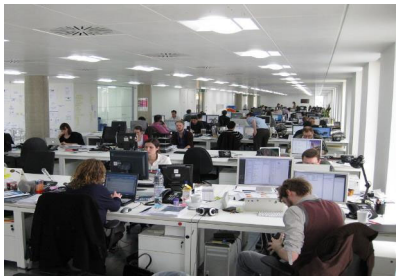
Biosafety Level 3 Lab (BSL-3) would be warranted for work with SARS-CoV-2



Copyright © 2021

6

Most indoor spaces are simply not designed to protect people from exposure to airborne pathogens



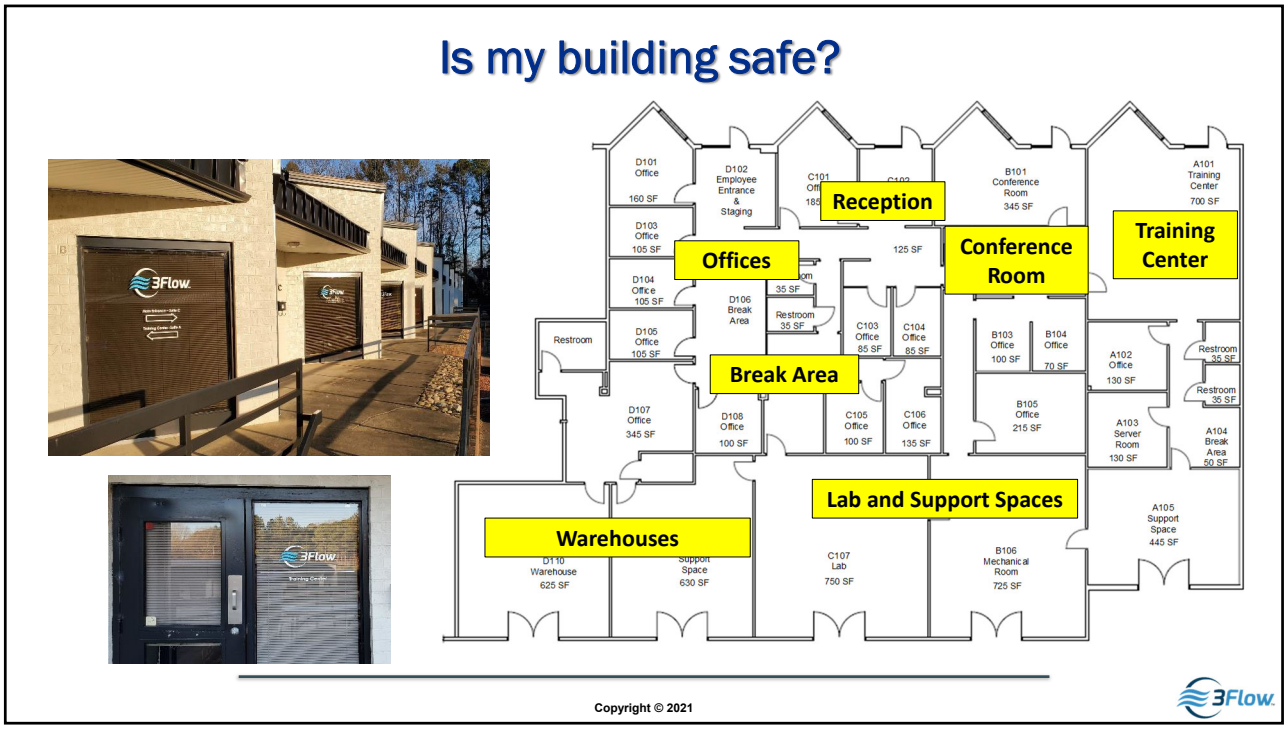
Copyright © 2021

7

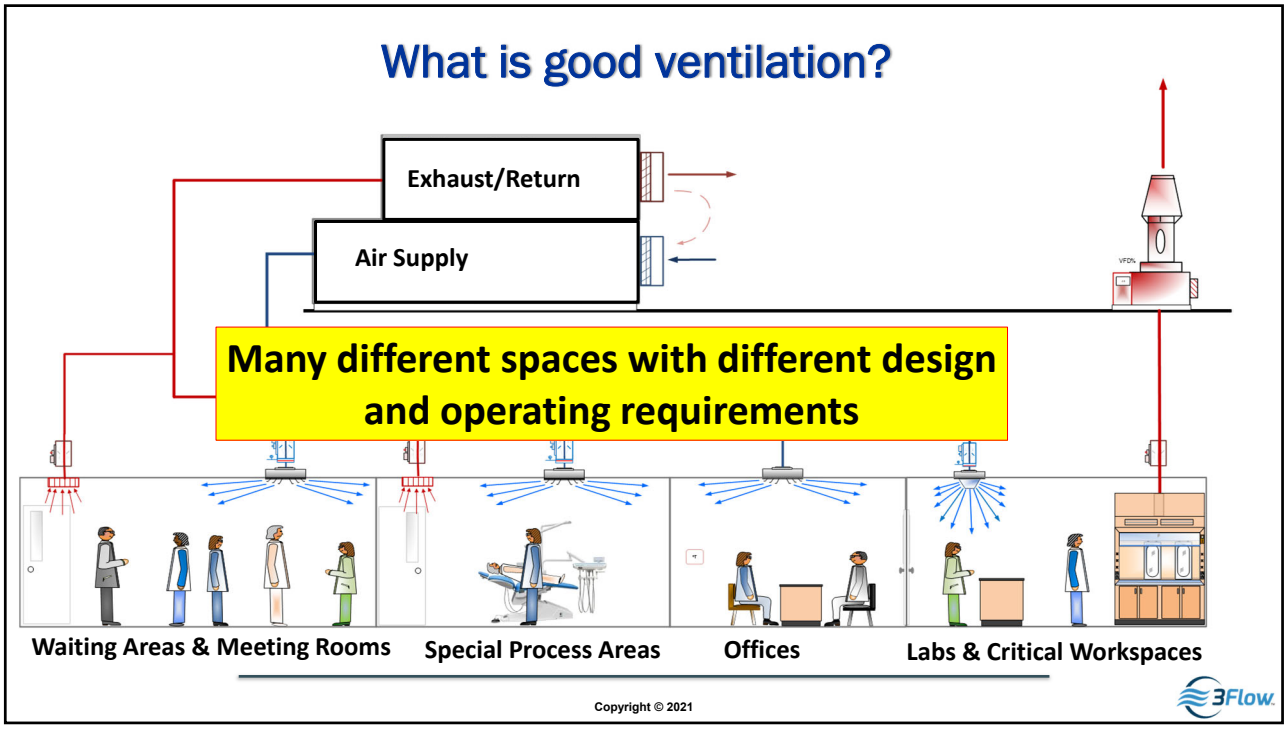
In addition, infected people are mobile emission sources … and we don't know who they are!

Copyright © 2021

8

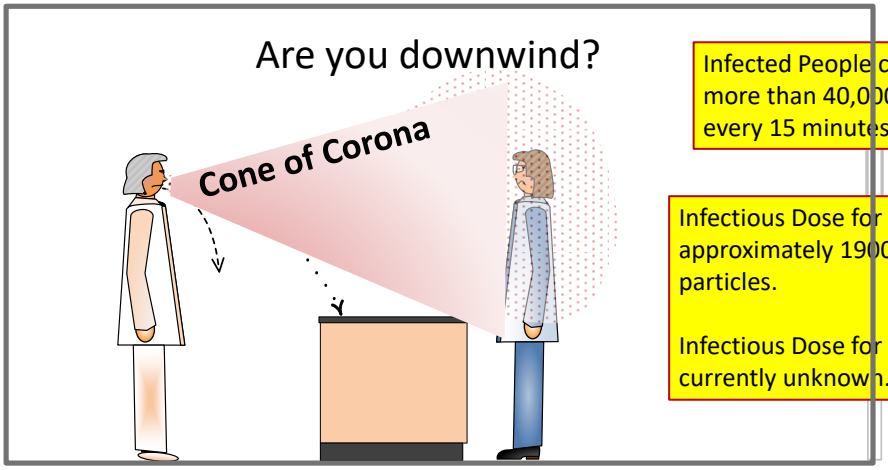

Is my building safe?
Reception
Offices
Conference Room
Training Center
Break Area
Lab and Support Spaces
Warehouses
D101 Office 160 SF
D102 Employee Entrance & Staging
B101 Conference Room 345 SF
A101 Training Center 700 SF
D103 Office 105 SF
125 SF
D104 Office 105 SF
D106 Break Area
35 SF
Restroom 35 SF
C103 Office 85 SF
C104 Office 85 SF
B103 Office 100 SF
B104 Office 70 SF
A102 Office 130 SF
Restroom 35 SF
Restroom
D105 Office 105 SF
D107 Office 345 SF
D108 Office 100 SF
C105 Office 100 SF
C106 Office 135 SF
B105 Office 215 SF
A103 Server Room 130 SF
A104 Break Area 50 SF
A105 Support Space 445 SF
D110 Warehouse 625 SF
Support Space 630 SF
C107 Lab 750 SF
B106 Mechanical Room 725 SF
Copyright © 2021
3Flow

9


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
Copyright © 2021
3Flow

10

Primary exposure occurs in the communal air space



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

Infectious Dose for Influenza approximately 1900 – 3000 viable particles.

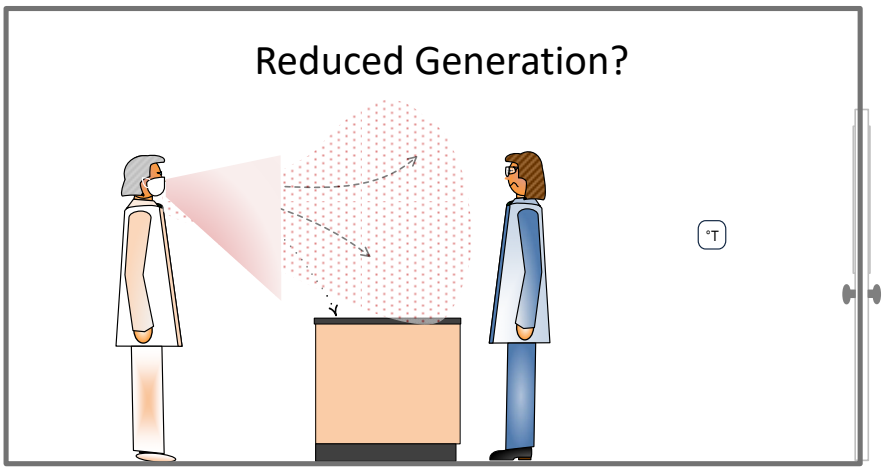
Infectious Dose for Coronavirus is currently unknown.

Infectious DOSE = Concentration x Duration

Copyright © 2021

11

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

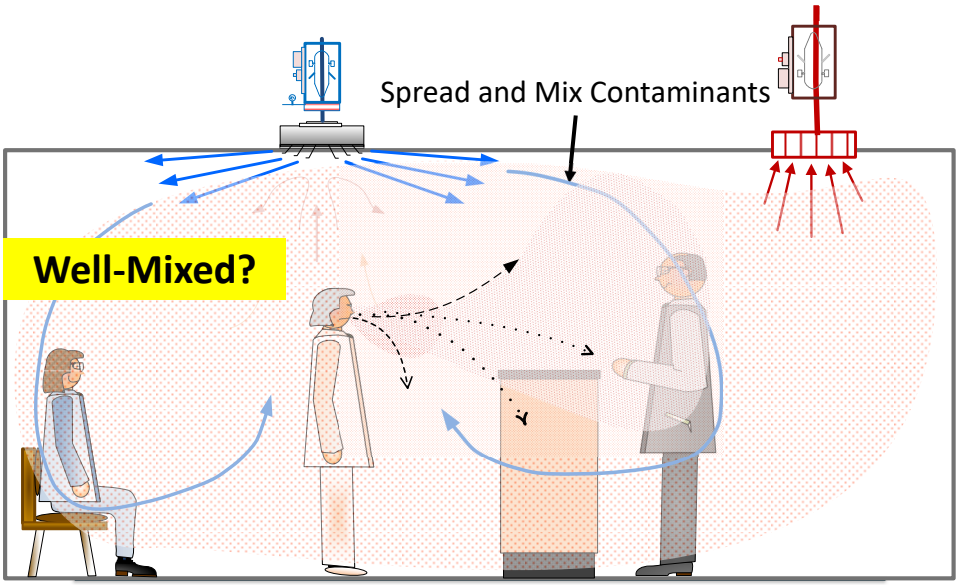


Concentration = Generation / Air Flow

Copyright © 2021

12

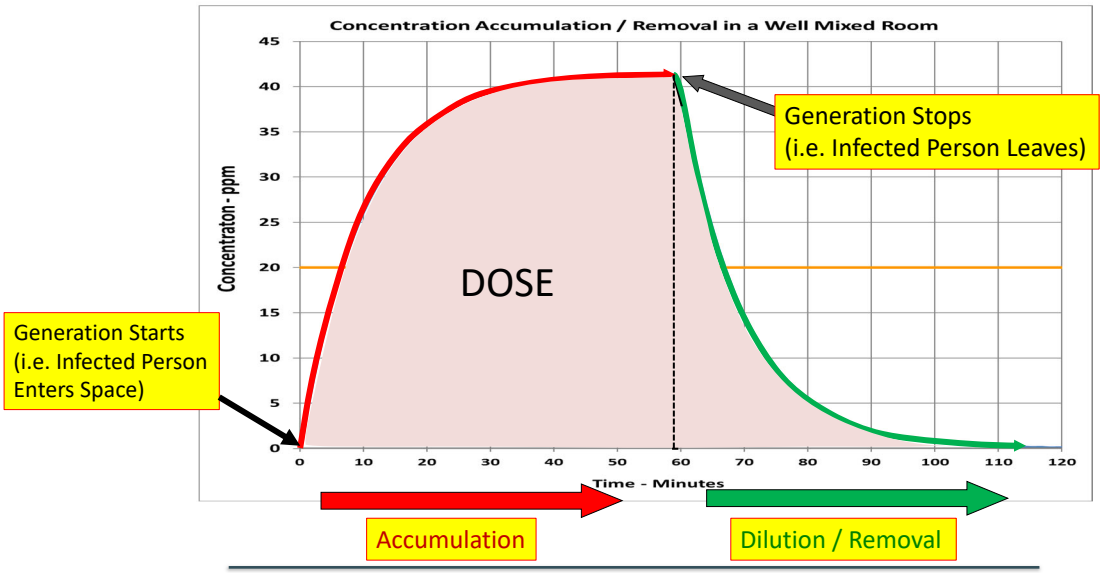
Is the ventilation system helping to mitigate risk?



Copyright © 2021

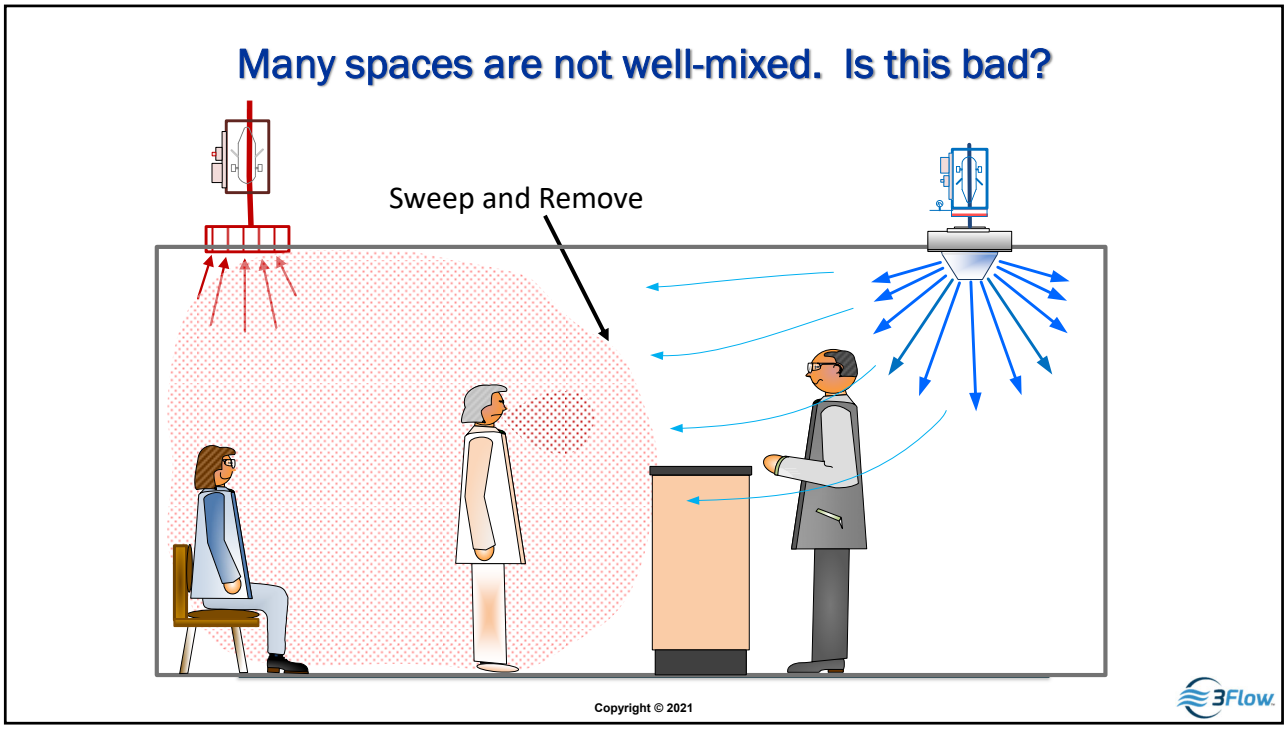
13

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

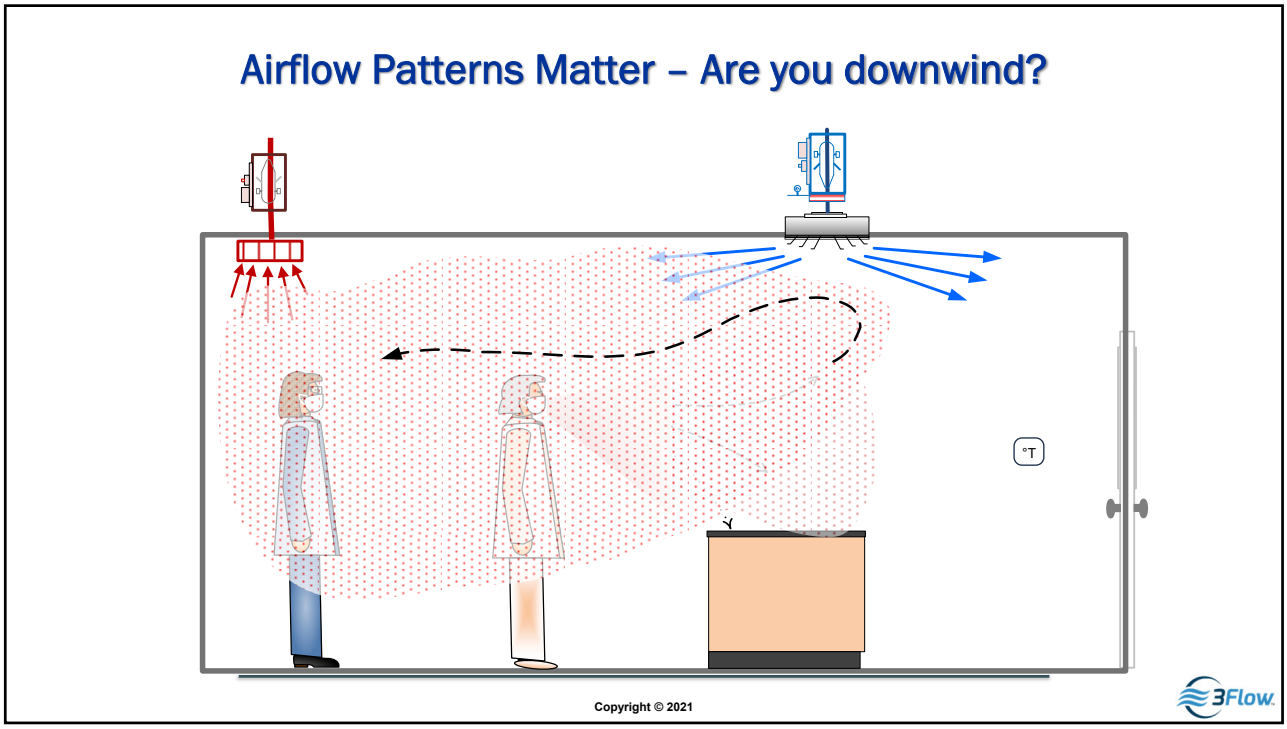


Copyright © 2021

14


Many spaces are not well-mixed. Is this bad?
Sweep and Remove
Copyright © 2021
3Flow

15


Airflow Patterns Matter – Are you downwind?
Copyright © 2021
3Flow

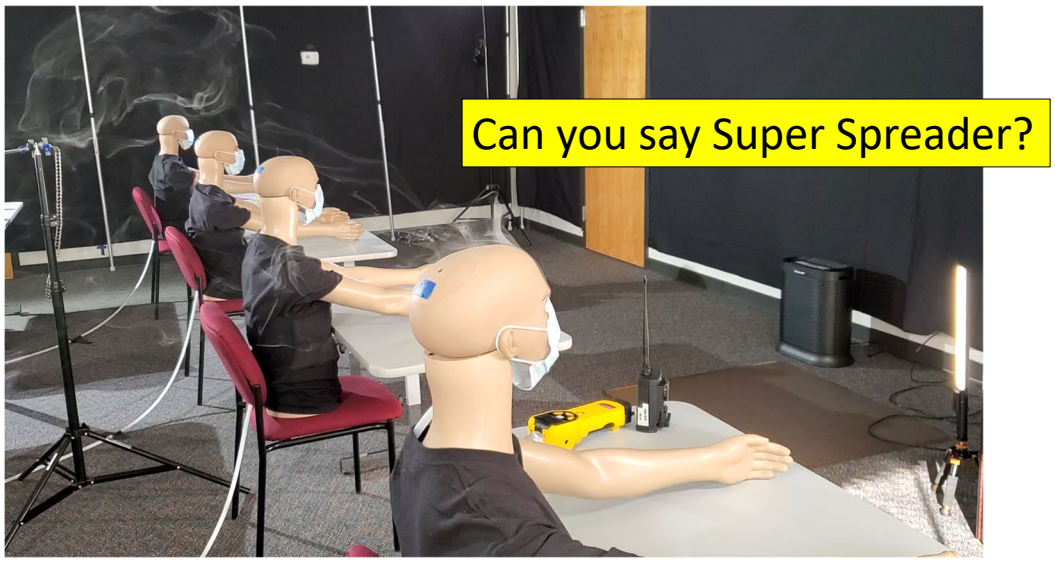
16

Airflow Patterns Matter - Rooms may not be well mixed

Copyright © 2021

17

Airflow Patterns Matter - Rooms may not be well mixed

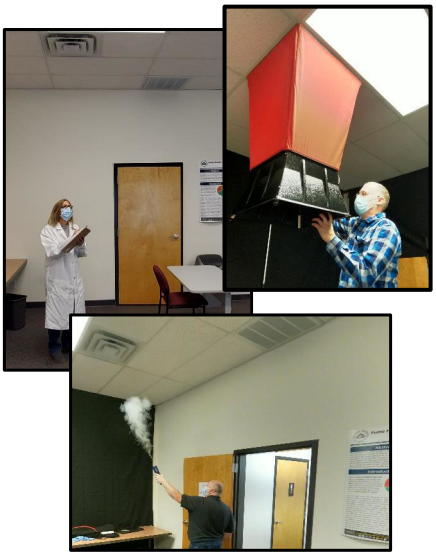


Copyright © 2021

18

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

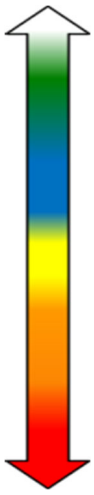


Copyright © 2021

19

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

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

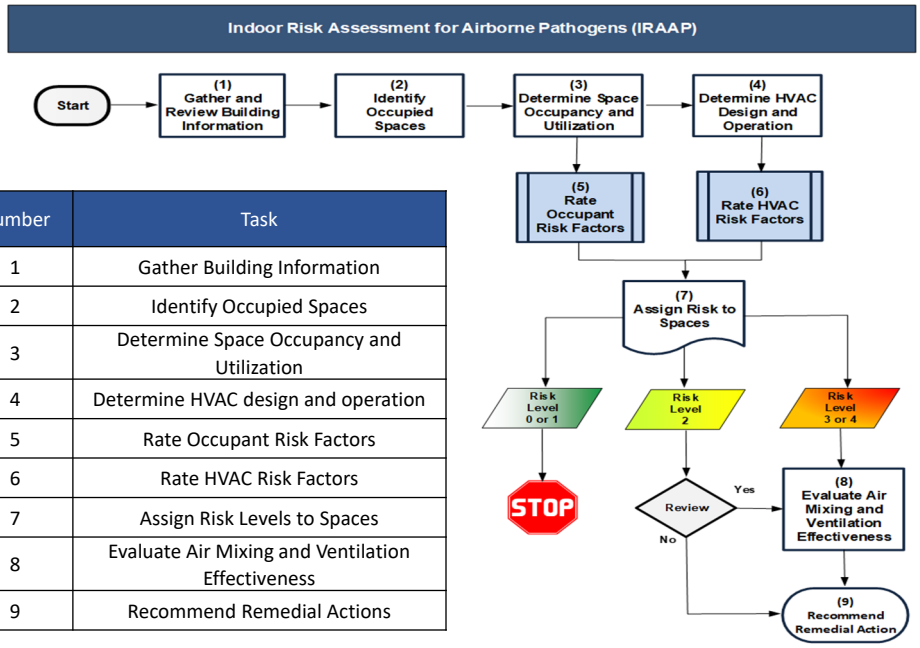


Spectrum of Risk

Copyright © 2021

20

Conducting an Indoor Risk Assessment for Airborne Pathogens



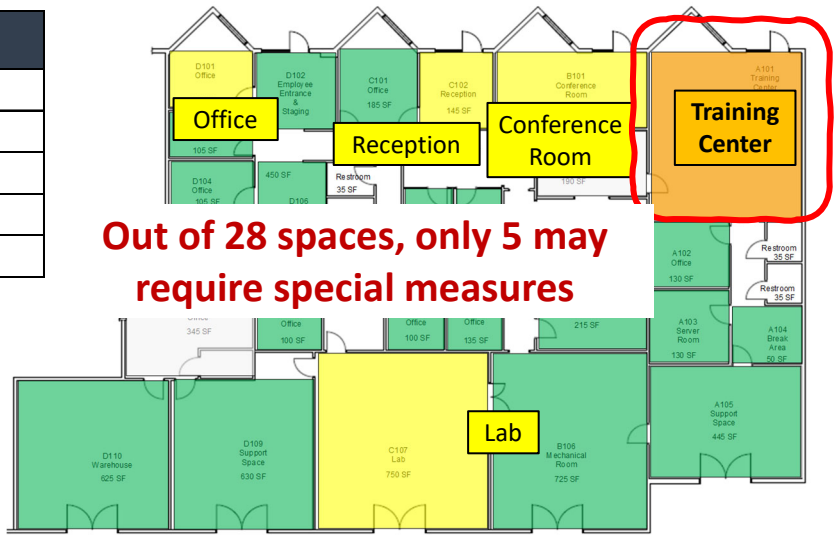
Number	Task
1	Gather Building Information
2	Identify Occupied Spaces
3	Determine Space Occupancy and Utilization
4	Determine HVAC design and operation
5	Rate Occupant Risk Factors
6	Rate HVAC Risk Factors
7	Assign Risk Levels to Spaces
8	Evaluate Air Mixing and Ventilation Effectiveness
9	Recommend Remedial Actions

Copyright © 2021

21

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

Risk Scale:	
0	Negligible
1	Low
2	Moderate
3	High
4	Extreme/Special

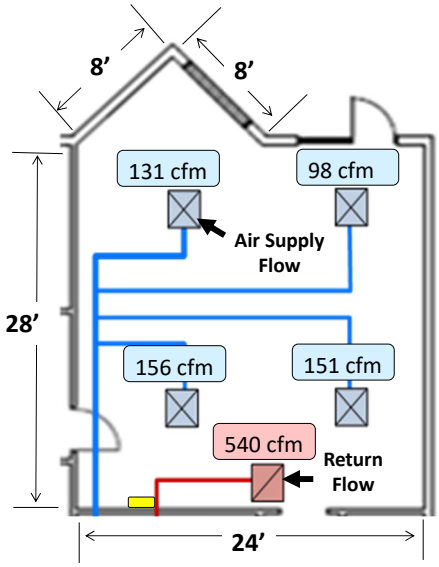


Out of 28 spaces, only 5 may require special measures

Copyright © 2021

22

Inspect and Measure HVAC Operation



Training Center

Area (A) = 704 ft^2
Height (H) = 10 ft
Volume (V) = 7,040 ft^3
Supply (Qs) – 536 cfm
Exhaust (Qex) – 540 cfm
Temp – 69 dF, RH - 46%

Air Change Rate

$$ACH = \frac{Q}{V}$$

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

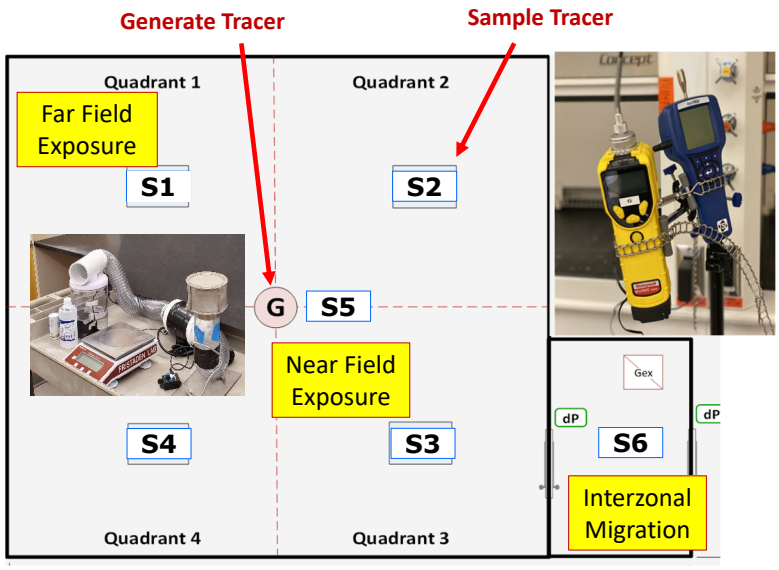
ACH = 4.6

Copyright © 2021

23

Ventilation Effectiveness can be measured

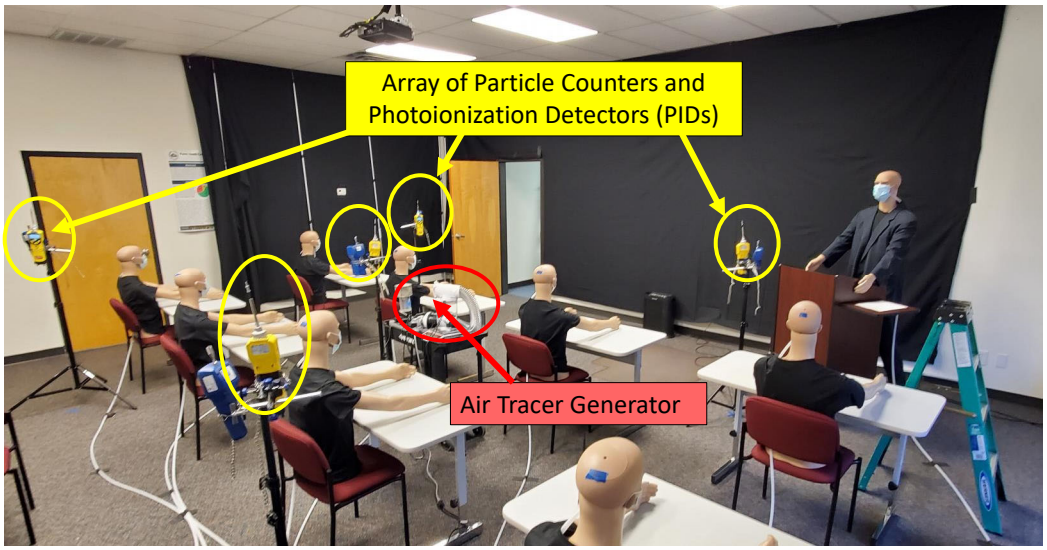
- Air Tracer Generation (G)
  (IPA and Particulates)
- Detectors Located at S1-S6
  (PIDs, Particle Counters)



Copyright © 2021

24

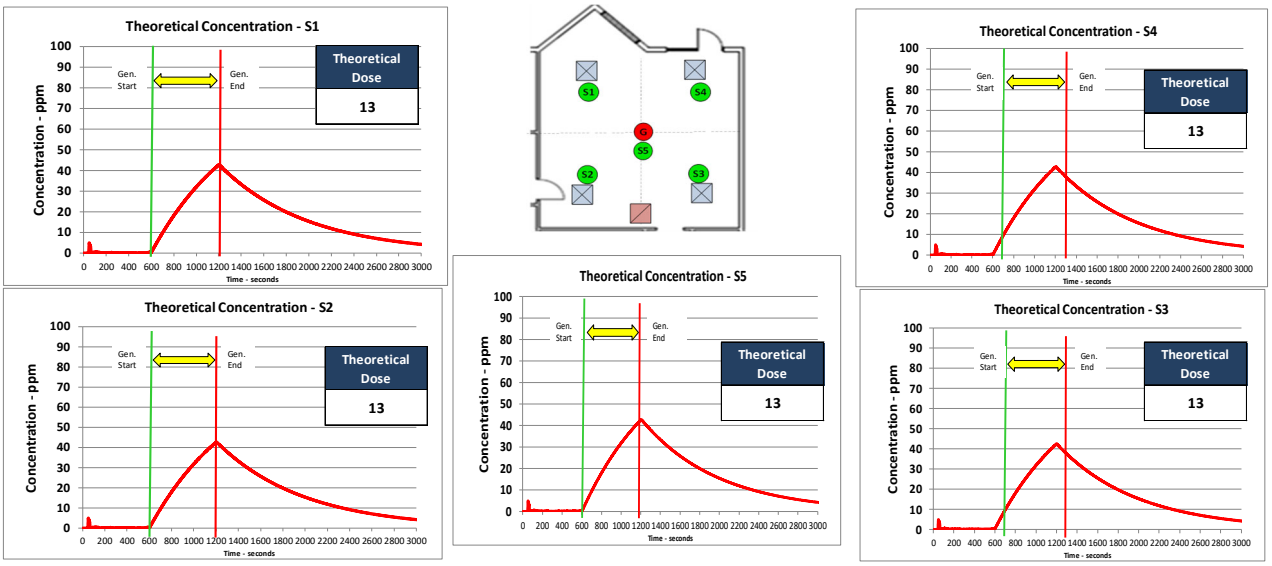
VEFF Tests use Air Tracers to challenge and quantify Ventilation Effectiveness



Copyright © 2021

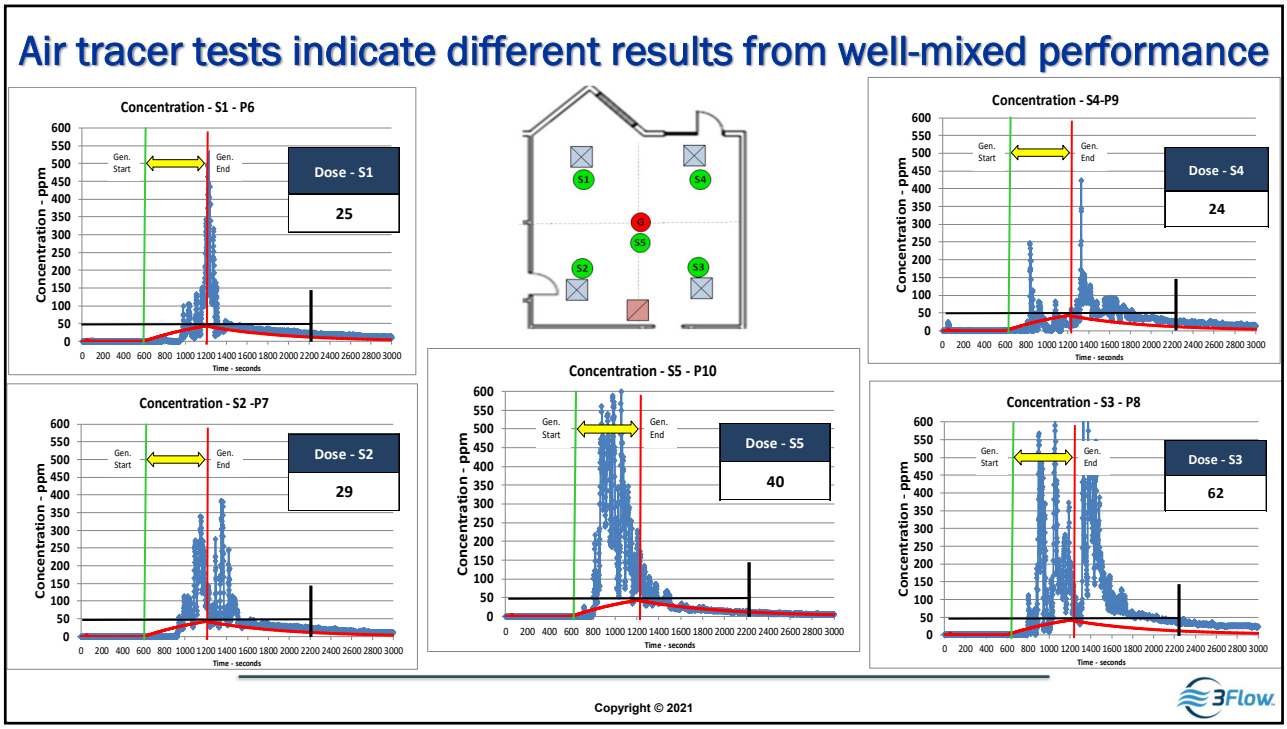
25

A Theoretical Well-Mixed Space would yield instantaneous and homogeneous concentration profile at all locations

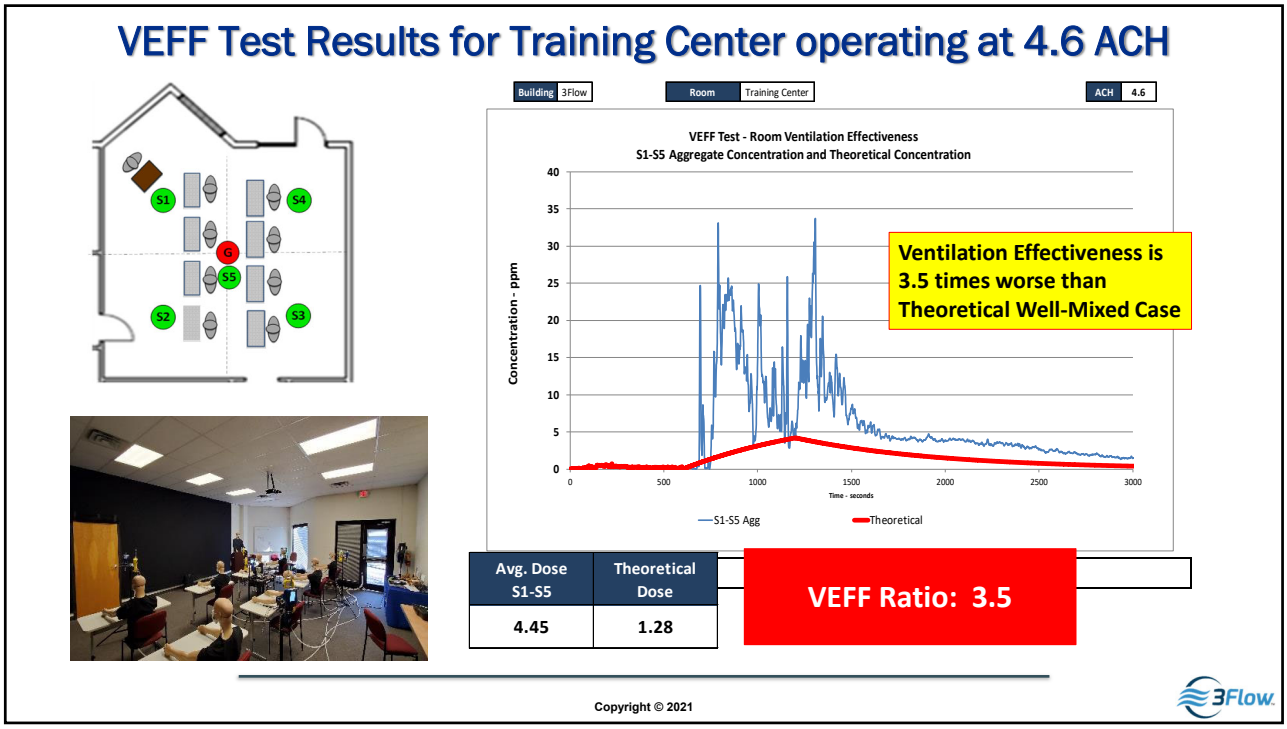


Copyright © 2021

26

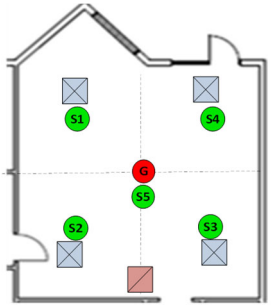

Air tracer tests indicate different results from well-mixed performance
Concentration - S1 - P6
Dose - S1
25
Concentration - S4-P9
Dose - S4
24
Concentration - S2 -P7
Dose - S2
29
Concentration - S5 - P10
Dose - S5
40
Concentration - S3 - P8
Dose - S3
62
Gen. Start
Gen. End
Concentration - ppm
Time - seconds
S1
S2
S3
S4
S5
G
Copyright © 2021
3Flow

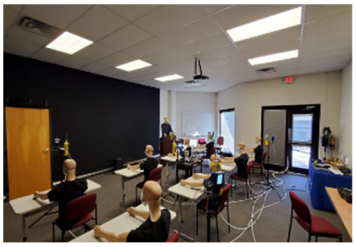
27

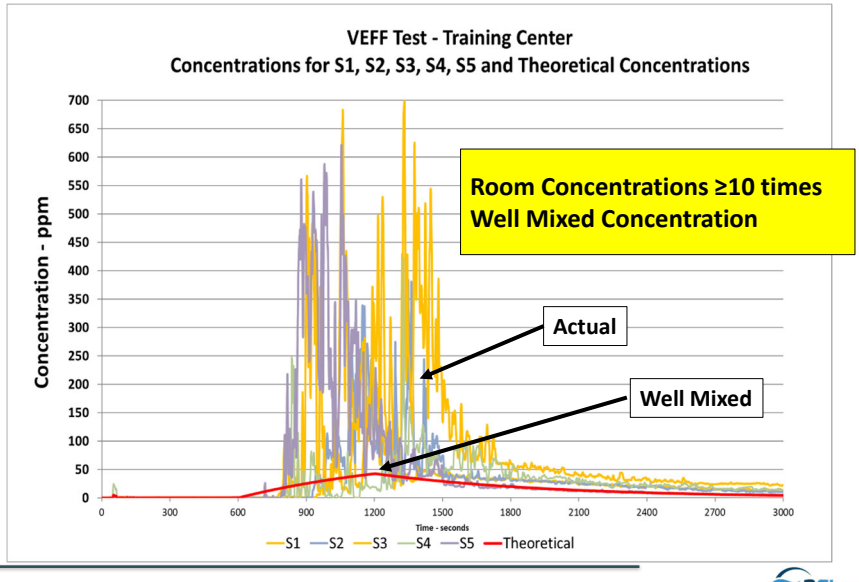

VEFF Test Results for Training Center operating at 4.6 ACH
Building 3Flow
Room Training Center
ACH 4.6
VEFF Test - Room Ventilation Effectiveness
S1-S5 Aggregate Concentration and Theoretical Concentration
Concentration - ppm
Time - seconds
S1-S5 Agg
Theoretical
Ventilation Effectiveness is 3.5 times worse than Theoretical Well-Mixed Case
Avg. Dose S1-S5
4.45
Theoretical Dose
1.28
VEFF Ratio: 3.5
Copyright © 2021
3Flow

28

Ventilation Effectiveness Tests in the Training Center







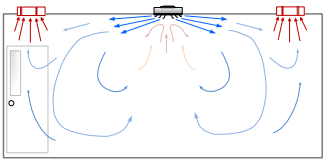
Copyright © 2021

29

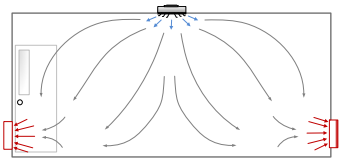
The risk and ventilation effectiveness may justify the need for additional safety measures such as Portable Air Cleaners

VEFF ≤ 1

Well-Mixed



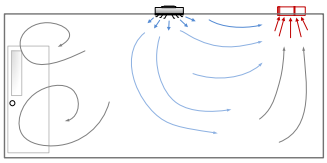
Good Sweep and Removal



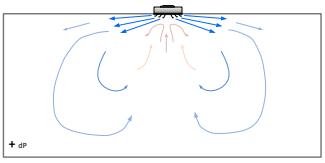
Okay with Adequate Flow

VEFF > 1

Short Circuiting

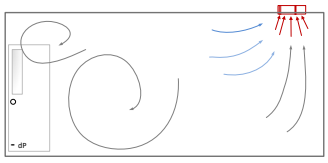


Supply Only, No Exhaust

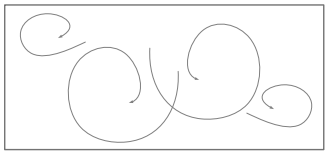


VEFF >> 1

Exhaust Only, No Supply



No Supply or Exhaust

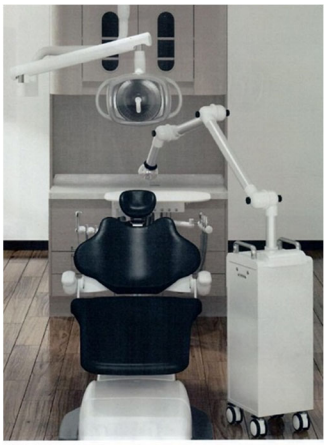


Consider HVAC Modifications or Portable Air Purifiers

Copyright © 2021

30

Consider special safety measures and use of Portable Air Cleaners

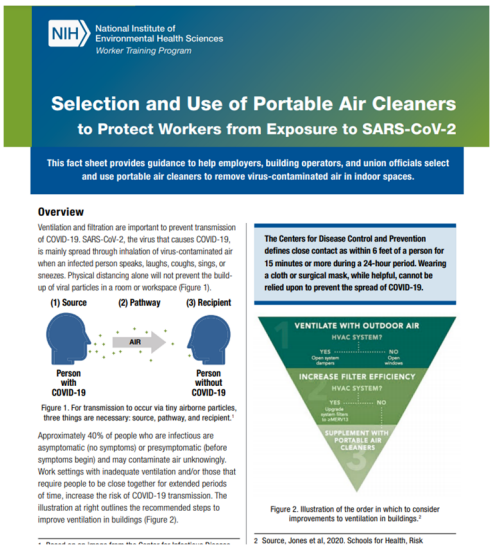


Copyright © 2021

31

NIEHS Fact Sheet – Selection 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



NIH National Institute of Environmental Health Sciences
Worker Training Program

Selection and Use of Portable Air Cleaners to Protect Workers from Exposure to SARS-CoV-2

This fact sheet provides guidance to help employers, building operators, and union officials select and use portable air cleaners to remove virus-contaminated air in indoor spaces.

Overview

Ventilation and filtration are important to prevent transmission of COVID-19. *SARS-CoV-2*, the virus that causes COVID-19, is mainly spread through inhalation of virus-contaminated air when an infected person speaks, laughs, coughs, sings, or sneezes. Physical distancing alone will not prevent the build-up of viral particles in a room or workspace (Figure 1).

(1) Source (2) Pathway (3) Recipient

AIR

Person with COVID-19 — Person without COVID-19

Figure 1. For transmission to occur via tiny airborne particles, three things are necessary: source, pathway, and recipient.[1]

Approximately 40% of people who are infectious are asymptomatic (no symptoms) or presymptomatic (before symptoms begin) and may contaminate air unknowingly. Work settings with inadequate ventilation and/or those that require people to be close together for extended periods of time, increase the risk of COVID-19 transmission. The illustration at right outlines the recommended steps to improve ventilation in buildings (Figure 2).

The Centers for Disease Control and Prevention defines close contact as within 6 feet of a person for 15 minutes or more during a 24-hour period. Wearing a cloth or surgical mask, while helpful, cannot be relied upon to prevent the spread of COVID-19.

VENTILATE WITH OUTDOOR AIR
HVAC SYSTEM?
YES — NO
INCREASE FILTER EFFICIENCY
HVAC SYSTEM?
YES — NO
SUPPLEMENT WITH PORTABLE AIR CLEANERS

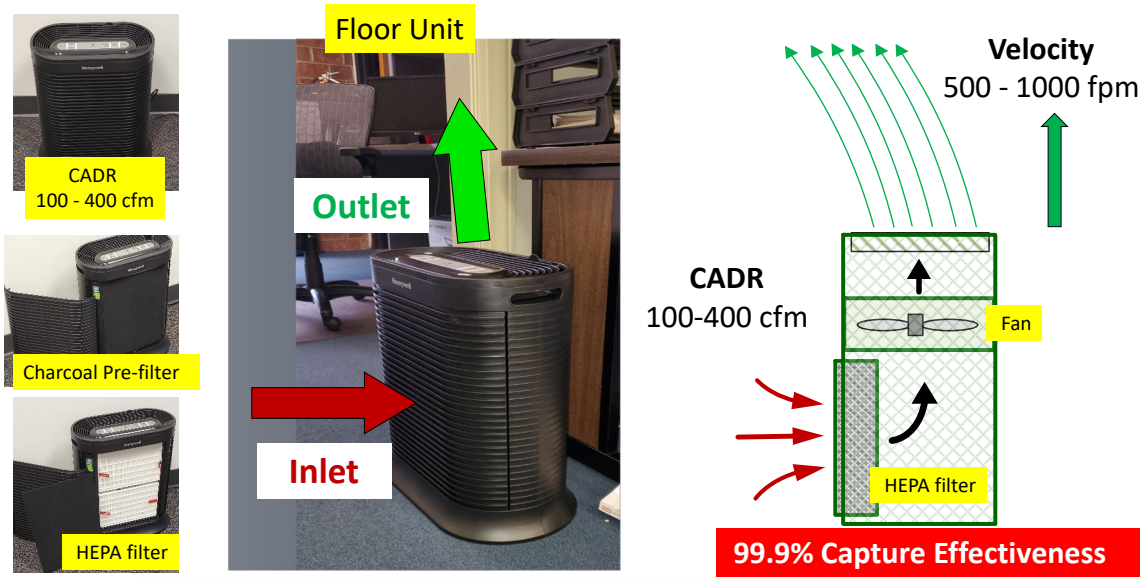
Figure 2. Illustration of the order in which to consider improvements to ventilation in buildings.[2]

2 Source, Jones et al, 2020. Schools for Health, Risk

Copyright © 2021

32

Portable Air Cleaners should include internal fans and filters

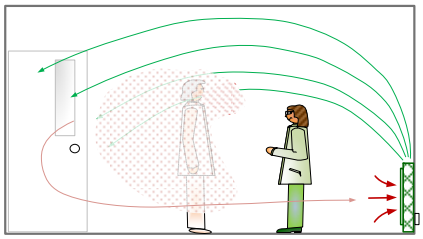


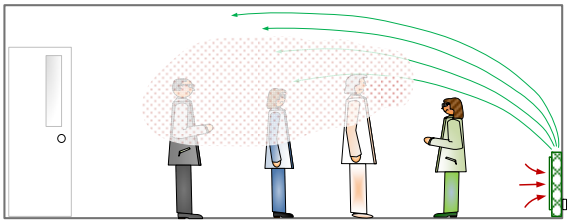
Copyright © 2021

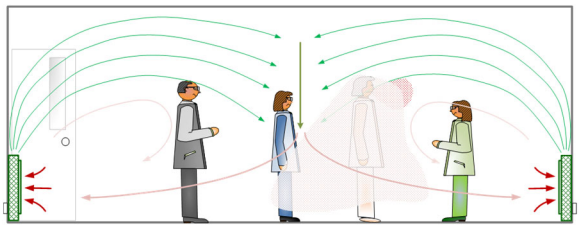
33

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







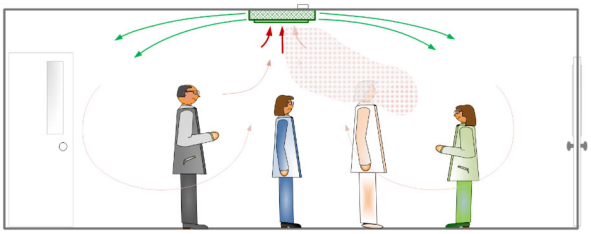
Copyright © 2021

34

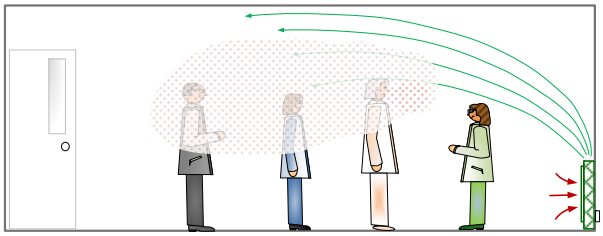
Consider Location of Portable Air Cleaners

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

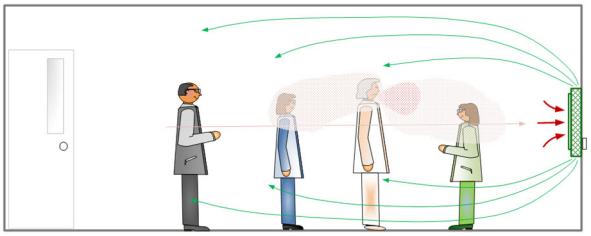
1 – Ceiling Mounted



3 – Floor Mounted



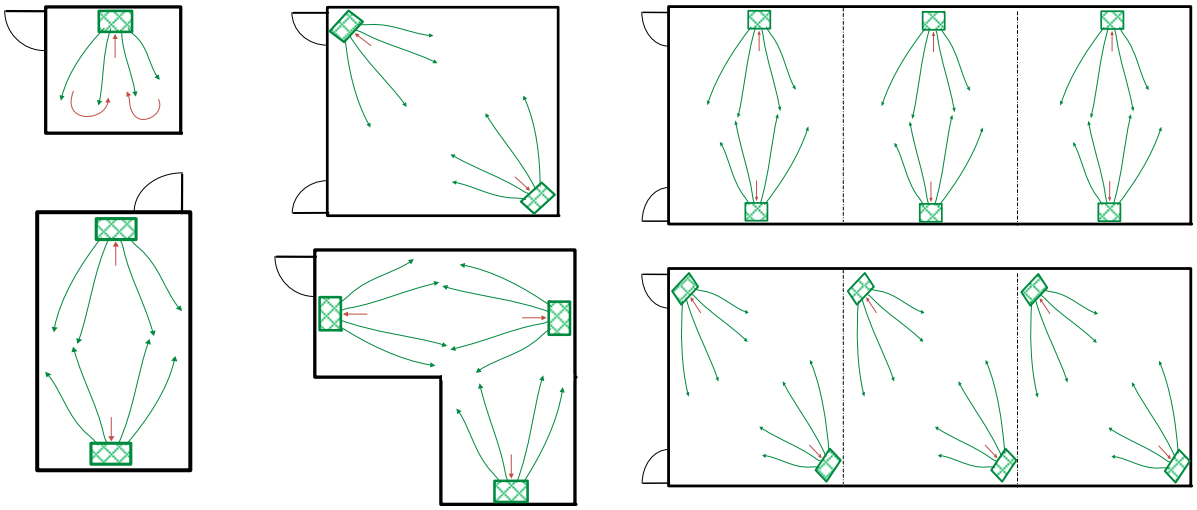
2 – Side Wall Mounted



Copyright © 2021

35

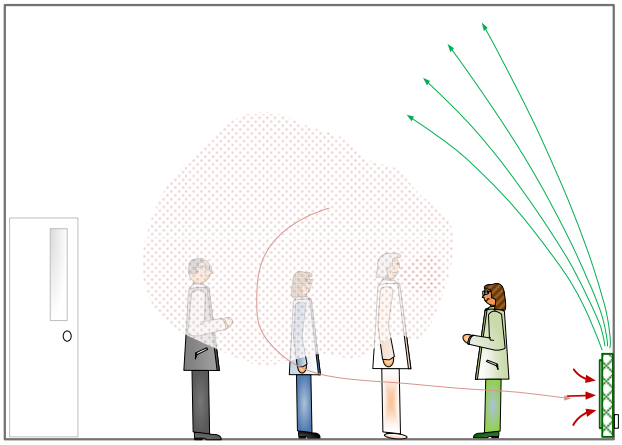
Consider placement of portable air purifiers to maximize dilution and removal of contaminants

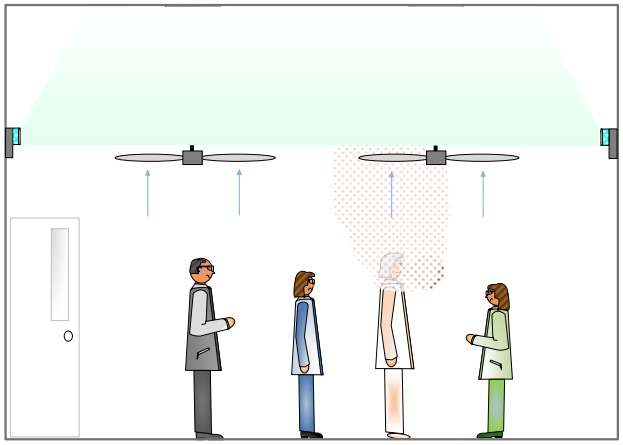


Copyright © 2021

36

High ceilings may pose problems for portable air cleaners





Mixing and removal may be compromised

Other techniques such as UVGI may be applicable

Copyright © 2021

37

Consider Air Purifier Noise Levels

Unit OFF

Unit ON – LOW

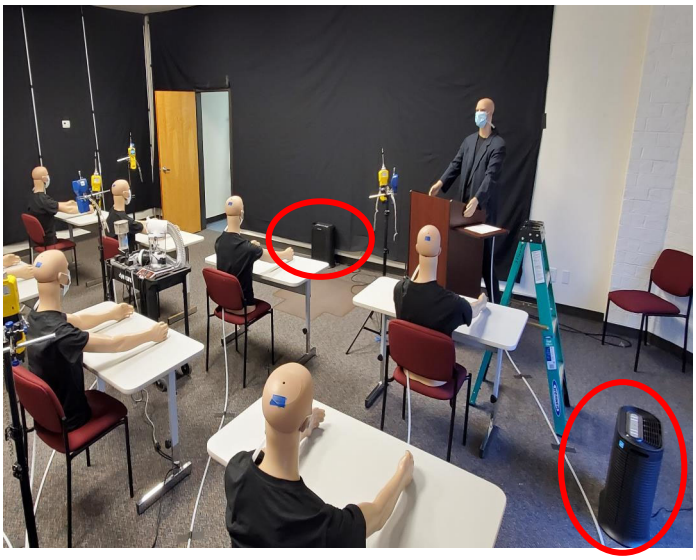
Unit ON - HIGH

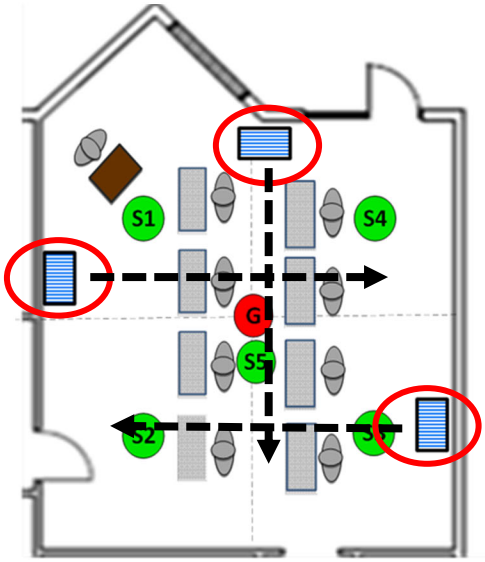
40 dB – Quite Library
60 dB – Conversation
80 dB – Loud Music

Copyright © 2021

38

Portable Air Cleaners were installed in the Training Center



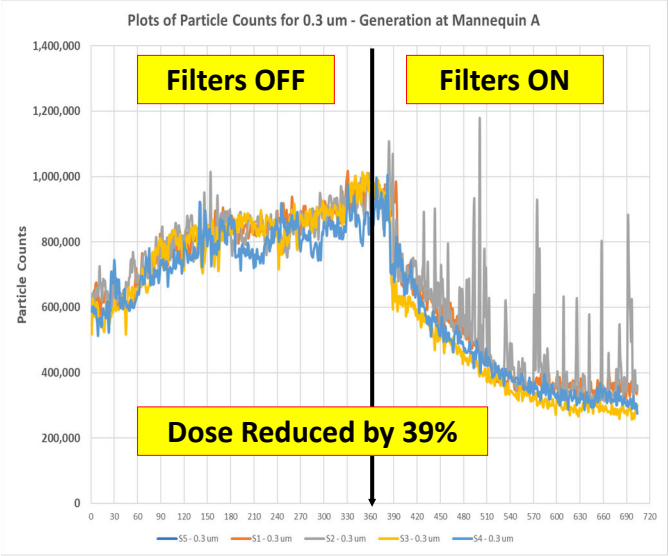


Copyright © 2021

39

The Portable Air Cleaners reduced exposure dose

VEFF Test – Generation at Mannequin A

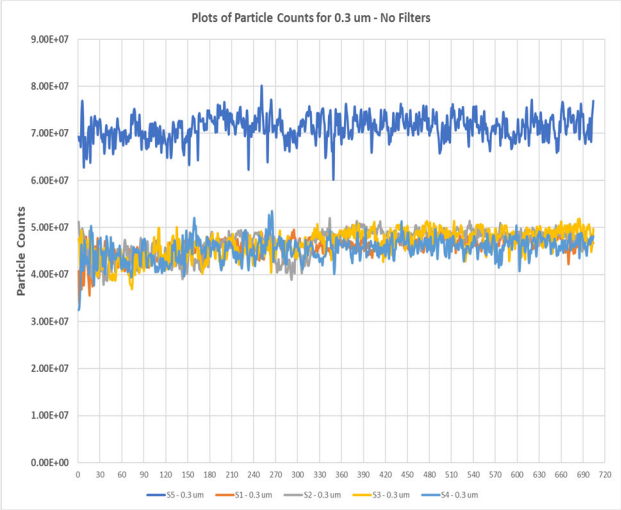


Copyright © 2021

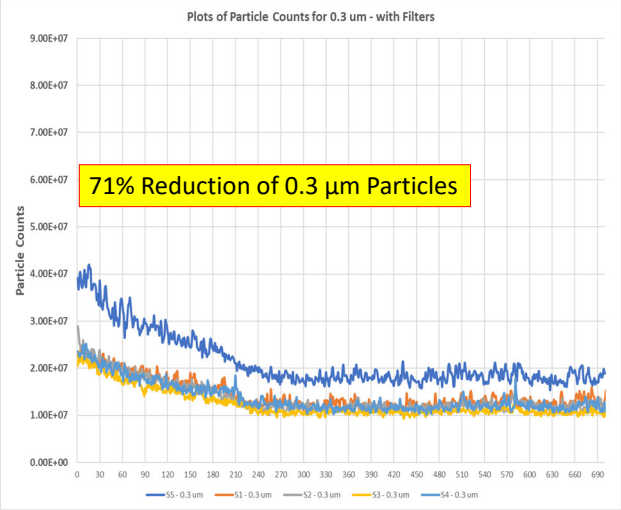
40

VEFF Tests – the portable air filters reduced exposure dose

VEFF Test – Filters OFF



VEFF Test – Filters ON

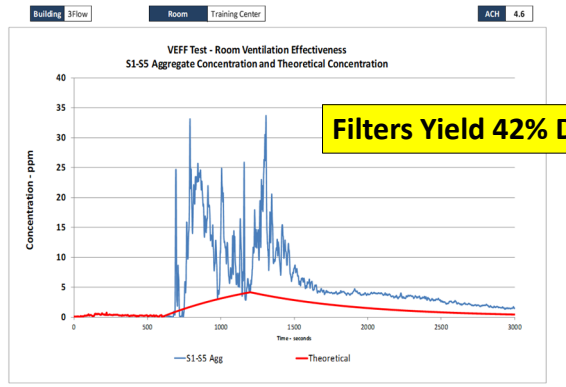


Copyright © 2021

41

The Portable Air Cleaners improved ventilation effectiveness

Filters OFF

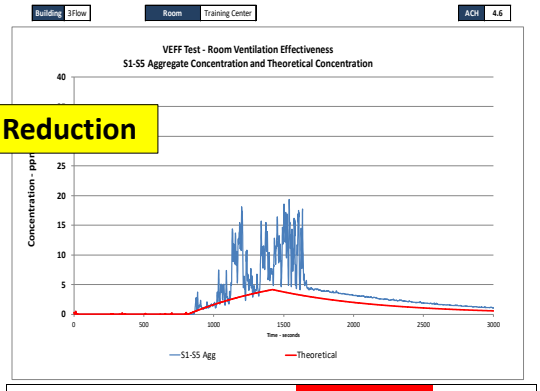


VEFF Factor 3.48

Avg. Dose S1-S5	Theoretical Dose
4.45	1.28

VEFF Ratio: 3.5

Filters ON



VEFF Factor 2.04

Avg. Dose S1-S5	Theoretical Dose
2.60	1.27

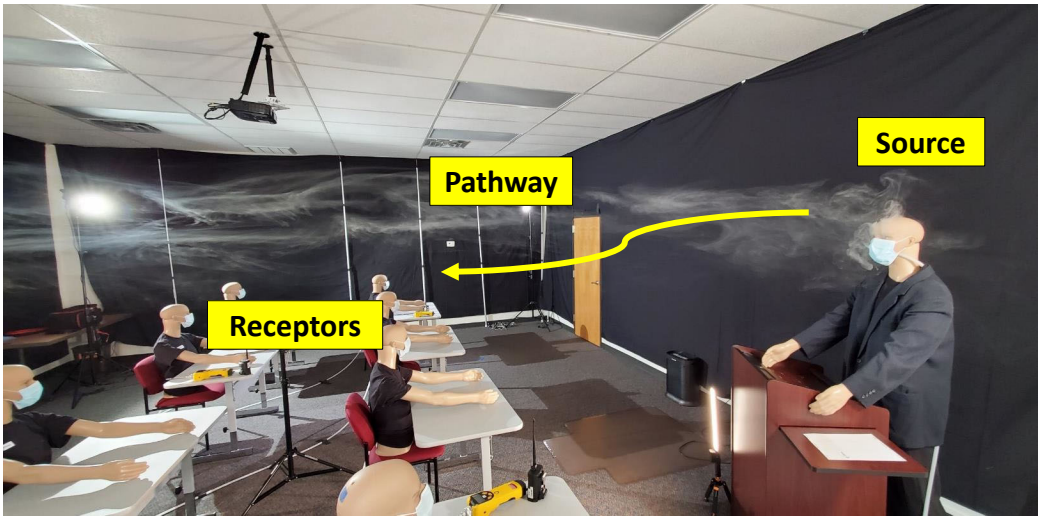
VEFF Ratio: 2.0

Filters Yield 42% Dose Reduction

Copyright © 2021

42

Consider the Sources, Pathways, and Receptors



Copyright © 2021

43

Implement Safety Measures and Manage Risk

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

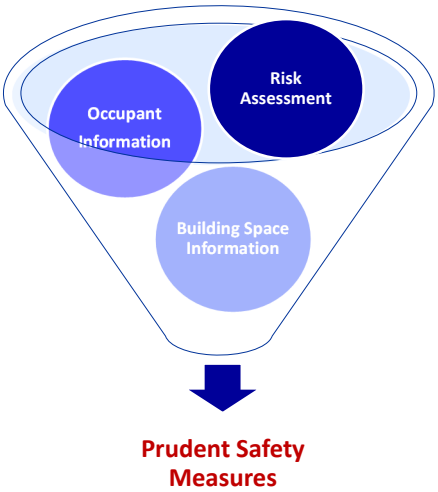
Item	Prudent Measures to Reduce Risk	Risk Level				
		0	1	2	3	4
1	Administrative Controls	X	X	X	X	X
2	Wear Masks and Respirators		X	X	X	X
3	Distancing and Physical Isolation (where possible)		X	X	X	X
4	Test and Verify HVAC Function		X	X	X	X
5	Consider Airflow Modifications (e.g. Supply / Exhaust)			X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

Copyright © 2021

44

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

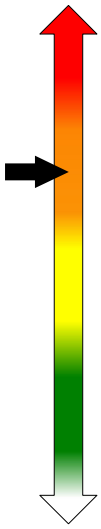


Copyright © 2021

45

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

Copyright © 2021

46

Thank You!

Stay Safe – Stay Upwind

Thomas C. Smith
919-319-4290
tcsmith@3flow.com
www.3flow.com

Copyright © 2021

47