Corona Virus from Indoor Air Quality Perspective

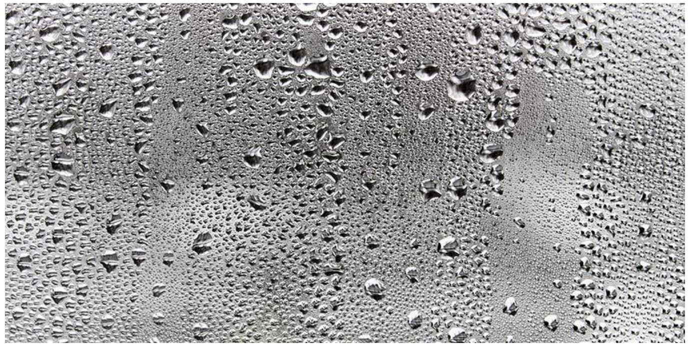
What is Indoor Air Quality (IAQ)?

- Indoor Air Quality (IAQ) refers to:
    1. the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants.
    2. Understanding and controlling common pollutants indoors can help reduce your risk of indoor health concerns.
- Health effects from indoor air pollutants may be experienced soon after exposure or, possibly, years later.

What are the Symptoms of low IAQ?

Still Indoor Air

+



Excessive humidity

=

Molds and Odors

- Effect on People:

Nausea and Headaches

Respiratory Issues

Fatigue

What are the Symptoms of low IAQ?

- Increase is other contaminants including:
  - Carbon Monoxide (CO).
  - Oxides of Nitrogen (NO_X).
  - Oxides of Sulfer (SO_X).
  - Carbon Dioxide (CO_2).
  - Particulate Matter(PM2.5, PM 10)
  - Volatile organic compounds (E.g. Formaldehyde HCHC)

Short-term Heath Effects

- Irritation of eyes, nose, and throat,
- headaches,
- dizziness,
- Fatigue
- Colds or other viral infections
- The likelihood of immediate reactions to indoor air pollutants depends on:
    1. age
    2. preexisting medical conditions
    3. individual sensitivities and allergies

Long-Term Health Effects

- Respiratory diseases,
- Heart disease
- cancer,
- Long-term effect can be severely debilitating or fatal.
- Therefore, it is prudent to try to improve the indoor air quality in your home even if symptoms are not noticeable.

Sick
Building Syndrome

(SBS)

Situations in which building occupants experience acute health or comfort effects that appear to be linked to time spent in a particular building, but where no specific illness or cause can be identified.

The complaints may be localized in a particular room or zone, or may be spread throughout the building. Occupants experience relief of symptoms shortly after leaving the building.

Why is IAQ Important?

- People spend nearly 90% of their time indoors.
- Indoor human exposure to air pollutants is 2-5 times more than outdoor exposure.
- Speed and accuracy used to measure productivity.
- Indoor air quality improves level of productivity.
- Reduces absenteeism and upgrading investment.
- Correlation exists between low productivity and dissatisfaction.

Causes of IAQ Deficiencies

- Lack of Ventilation Air
- Overcrowding.
- Smoking.
- Infiltration (Outdoor penetration of particles)
- Off gassing from materials and mechanical equipment.
- Improper temperature and relative humidity
- Inadequate filter level and placement

What are the Causes of lower IAQ?

Improper ducting installations

Low building ventilation

Indoor Overcrowding

Perfume spraying, indoor human behavior

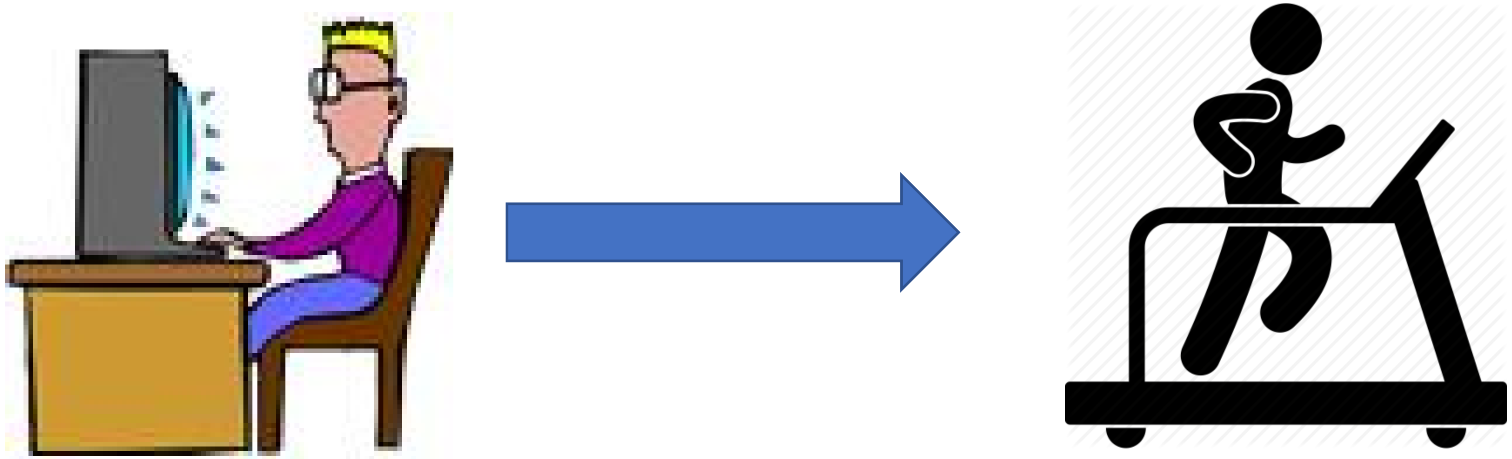
Poor filtration systems

Signs of IAQ Problems

- Noticeable indoor odors
- Excessive Humidity
- Presence of Molds
- Short-term symptoms presences like consistent coughing, sneezing…
- Lack of Air Movements

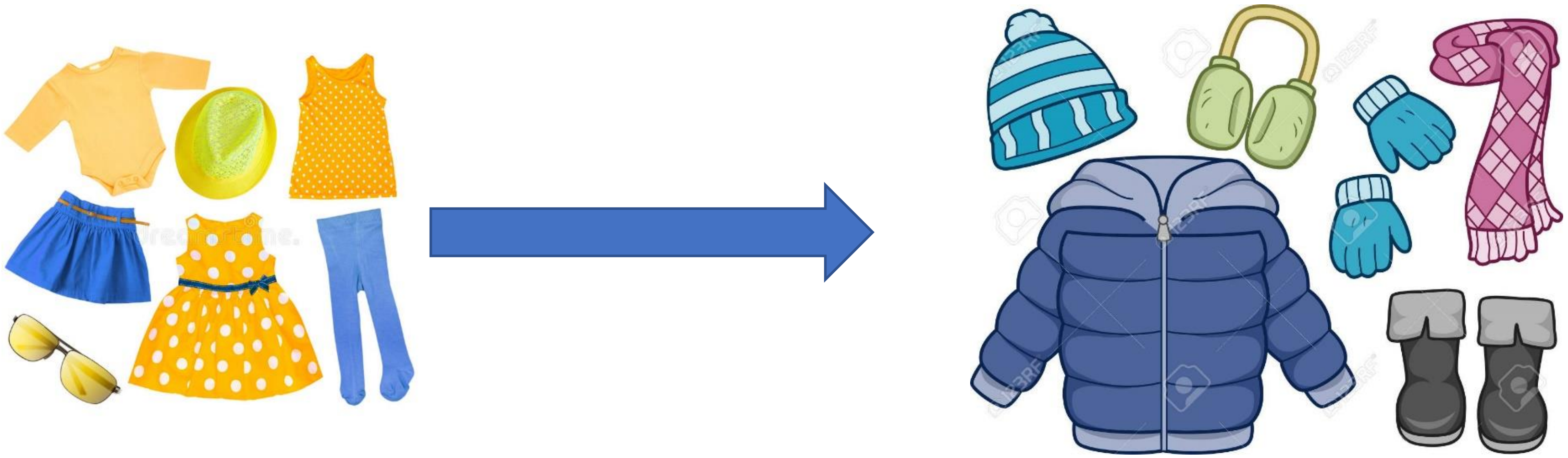
Thermal Comfort Factors

1. Activity of Occupants



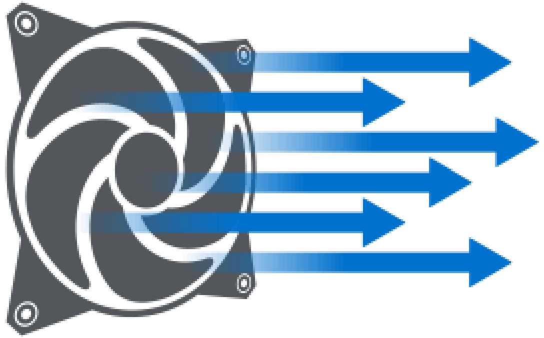
Activity could Range from desk work to gym workout

2. Clothing Level



Thermal Comfort Factors

3. Airflow

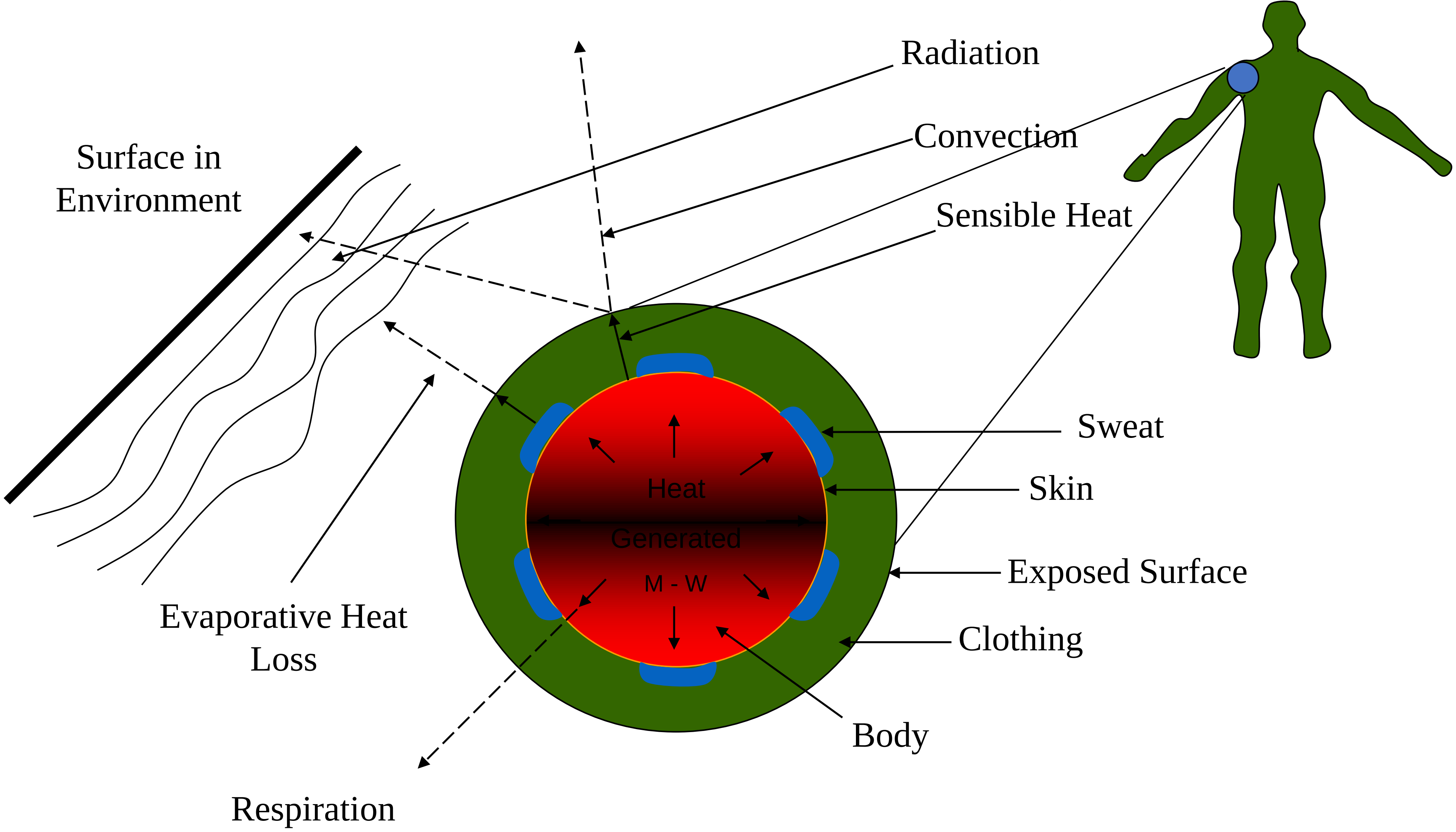


4. Temperature

5. Relative Humidity

6. Radiant Temperature

Thermal Interaction & Human Body



Thermal Comfort Index

- The predicted mean vote (PMV) is an index to measure thermal sensation of a human being.
- -3 cold, -2 cool, -1 slightly cool, 0 neutral, +1 slightly warm, +2 warm, +3 hot.

Types of Airborne Contaminants

- Microorganisms
- Particulate contaminants
- Gaseous contaminants
- Vaporous contaminants

Microorganisms

- They usually include viruses, bacteria and Fungi
- Examples of viruses:
  1. Influenza
  2. Corona (SARS-CoV-2)
  3. Common colds
  4. Mumps
- Examples of Bacteria
  1. Tuberculosis
  2. Pneumonic Plague
- Fungi usually results in Molds on the walls, ceiling, attic……

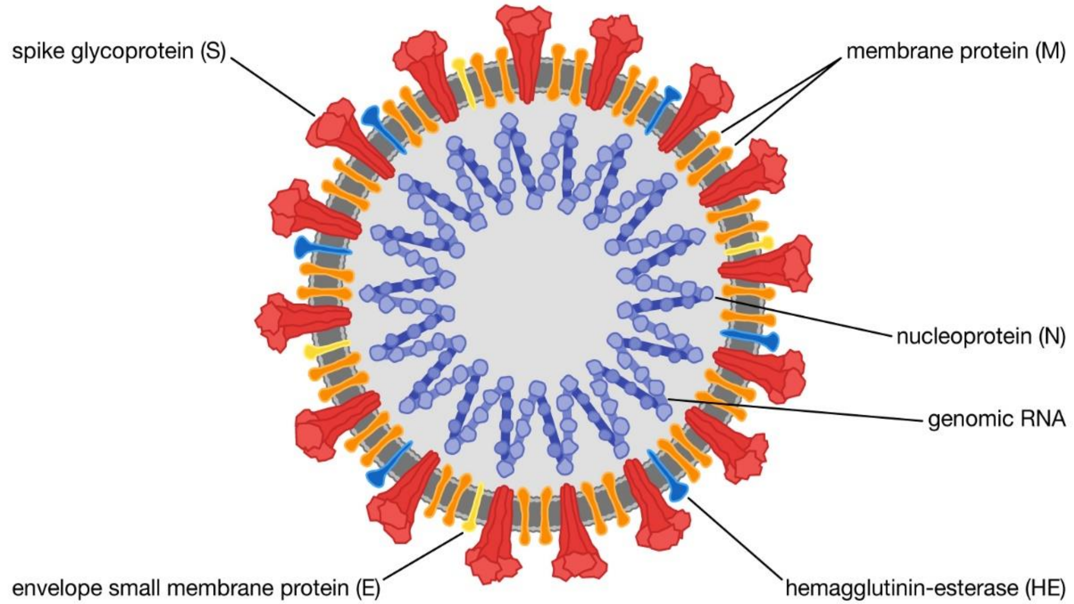
Microorganisms: Influenza

- **Disease Symptoms:** Fever, Runny or Stuffy Nose, Coughing, Sore Throats, Fatigue
- **Incubation Period**: 1 to 4 days
- **Duration of Illness:** Usually, 3-7 days, however, can last up to 2 weeks if complications are present (i.e. people with pre-existing conditions, senior citizens)
- **Annual Cases:** 3 to 5 million cases, with ½ million deaths (Worldwide)
- **Treatments:** Annual Flu Shot, Anti-viral drugs, and paracetamol painkillers to reduce the symptoms

Microorganisms: Corona (SARS-CoV-2)

- COVID-19 is caused by the SARS-CoV-2 virus
- Consisted of RNA strand for genetic material, drives into human cells and the virus gets replicated
- Lipid-membrane, with protein spikes
- May stay for 14 days or more in the body before symptoms appear if any.
- Average diameter 120 nm
- Total cases: 25.1-Million+
- Total Deaths: 850,000 +
- https://www.worldometers.info/coronavirus/
- Still in the First Wave of Infections

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)



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SARS-CoV-2 Transmission Debate

- WHO and CDC&P
  - The disease spreads primarily from person to person through small droplets from the nose or mouth, through coughs, sneezes, or speaking.
  - These droplets are relatively heavy, do not travel far and quickly sink to the ground
  - The virus may not be airborne
  - They are considering that the virus might be airborne

- ASHRAE's Position
  - Transmission of SARS-CoV-2 through the air is sufficiently likely that **airborne exposure** to the virus should be controlled. Changes to building operations, including the operation of heating, ventilating, and air-conditioning systems, can reduce airborne exposures.

WHO: World Health Organization
CDC&P: Center for Disease Control and Prevention

SARS-CoV-2 Transmission Debate

WHO

- March 29th article “Modes of transmission of virus causing COVID-19” stated that it was predominantly large droplet transmission at short range and that airborne transmission was very unlikely
- July 4th petition by 239 experts to WHO that the virus is airborne[1]
- July 9th scientific brief indicates that airborne transmission outdoor of medical procedures requires more study

CDC&P

- May 22nd media statement does not mention airborne transmission as a potential
- FAQ about SARS indicates “might be spread more broadly through the air (airborne spread) or by other ways that are not now known”
- SARS (original) also suggests possibility for COVID-19

1:Morawska et al (2020) https://doi.org/10.1093/cid/ciaa939

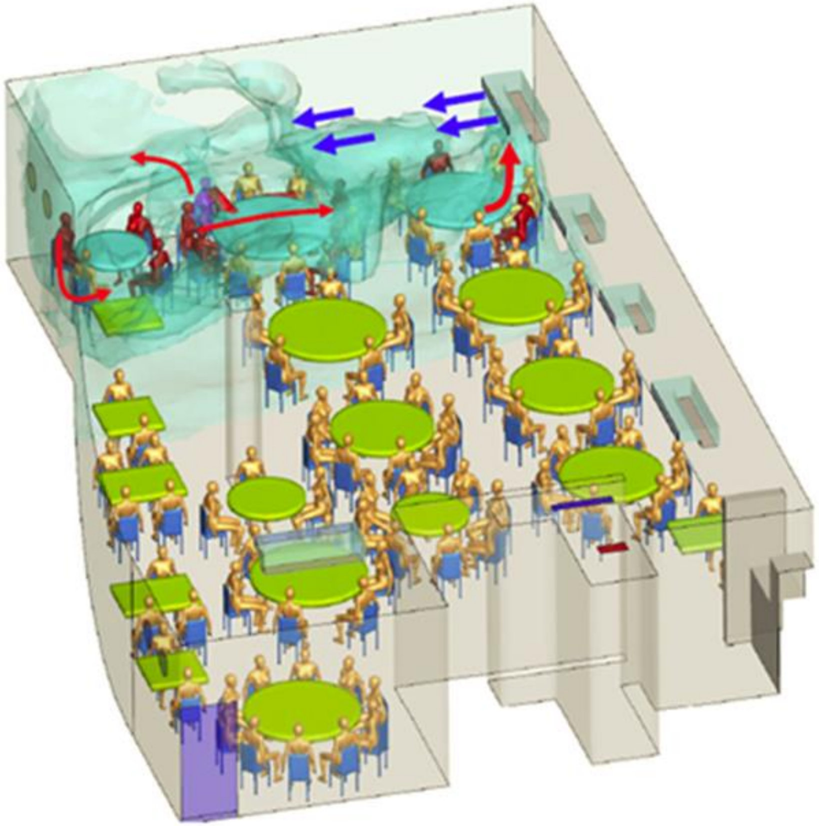
SARS-CoV-2 Transmission Debate

Unexplained COVID-19 “community spread” incidents cast doubt on claimed insignificance of airborne transmission,

Guangzhou, CHN restaurant

- 10 of 21 diners at three tables
- Infected by 1 person
- Distance of up to 5m (16 feet)

Poor ventilation and filtration



Li, et al. (2020) https://doi.org/10.1101/2020.04.16.20067728

SARS-CoV-2 Transmission Debate

Unexplained COVID-19 “community spread” incidents cast doubt on claimed insignificance of airborne transmission, e.g.

Skagit Valley, WA choir rehearsal

- 53 of 61 participants infected
- 2.5 hours of rehearsal
- Multiple “arrangement” of people
- Chairs 6 to 10 inches apart
- Unknown ventilation
- MERV 11 filters in furnace

Miller et al (2020) https://doi.org/10.1101/2020.06.15.20132027

SARS-CoV-2 Transmission Debate

Unexplained COVID-19 “community spread” incidents cast doubt on claimed insignificance of airborne transmission, e.g.

Call Center, South Korea

- 94 of 216 employees
- Blue dots indicate “positive”
- HVAC system unknown

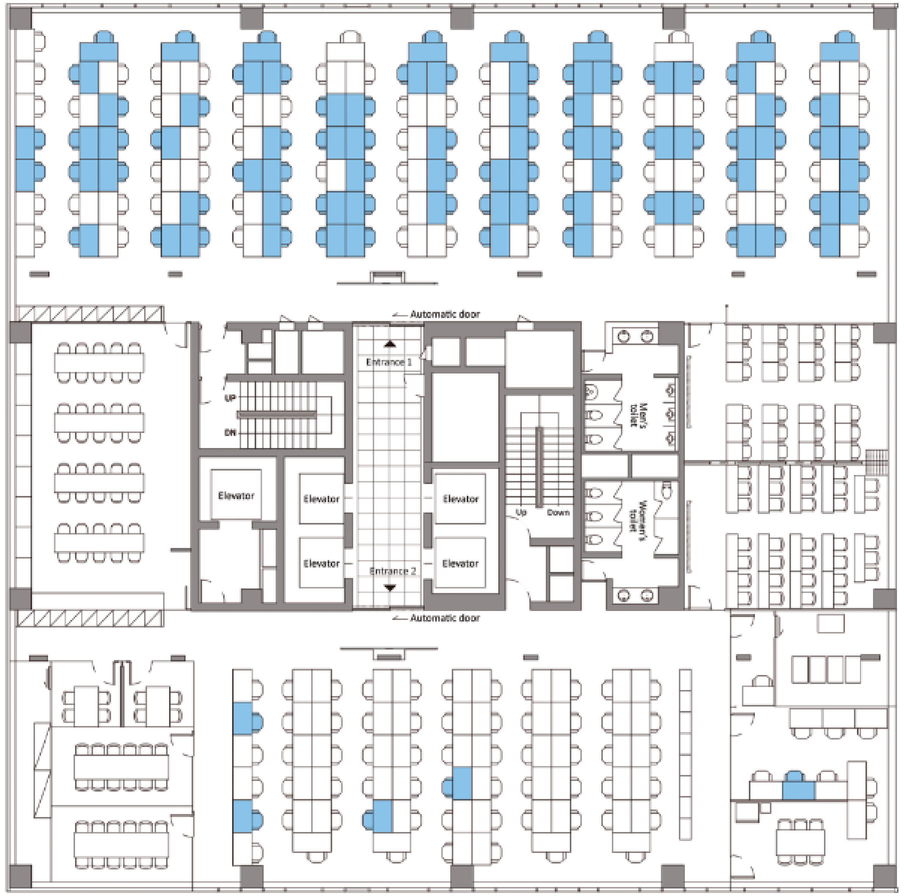


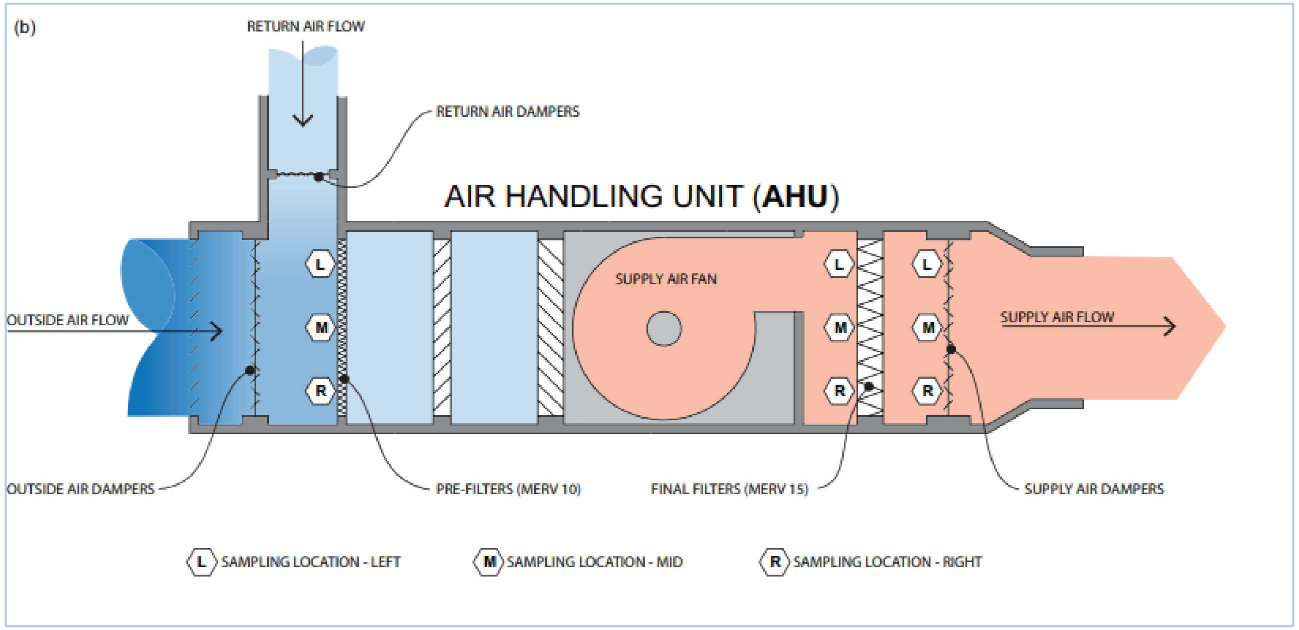
Figure 2. Floor plan of the 11th floor of building X, site of a coronavirus disease outbreak, Seoul, South Korea, 2020. Blue indicates the seating places of persons with confirmed cases.

Park et al (2020) https://wwwnc.cdc.gov/eid/article/26/8/20-1274_article#tnF1

SARS-CoV-2 Transmission Debate

Identification of SARS-CoV-2 RNA in Healthcare Heating, Ventilation, and Air Conditioning Units

- ~ 25% of samples had RNA
- Virality not checked
- Working on next phase
- MERV-15 Filters
- Working Hospital

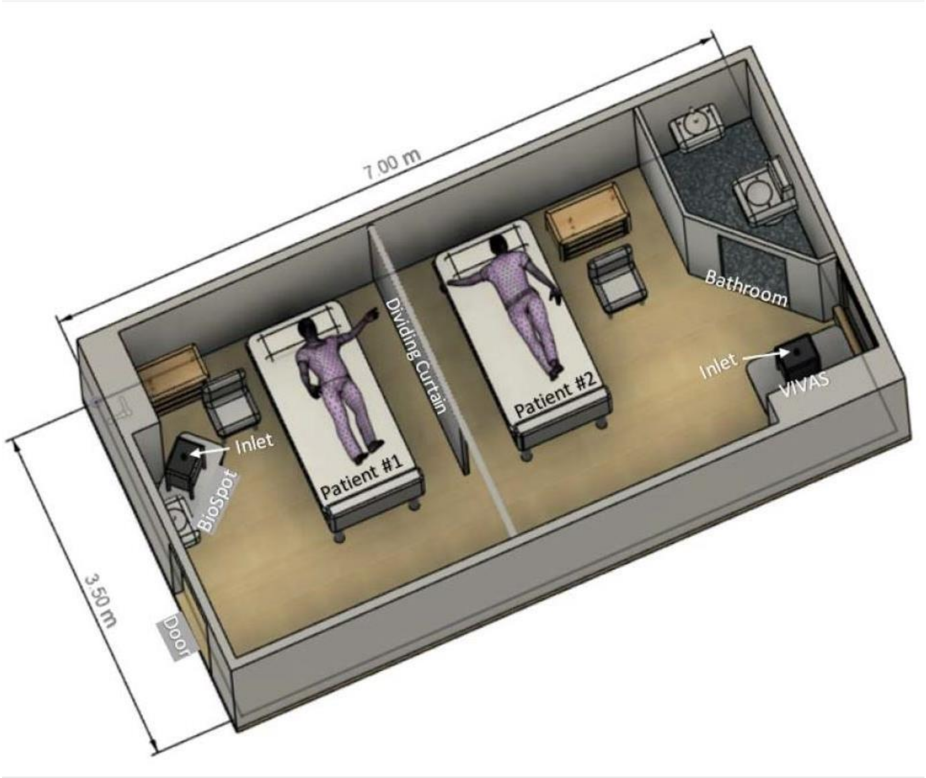


Horve, Dietz et al (2020) https://doi.org/10.1101/2020.06.26.20141085

SARS-CoV-2 Transmission Debate

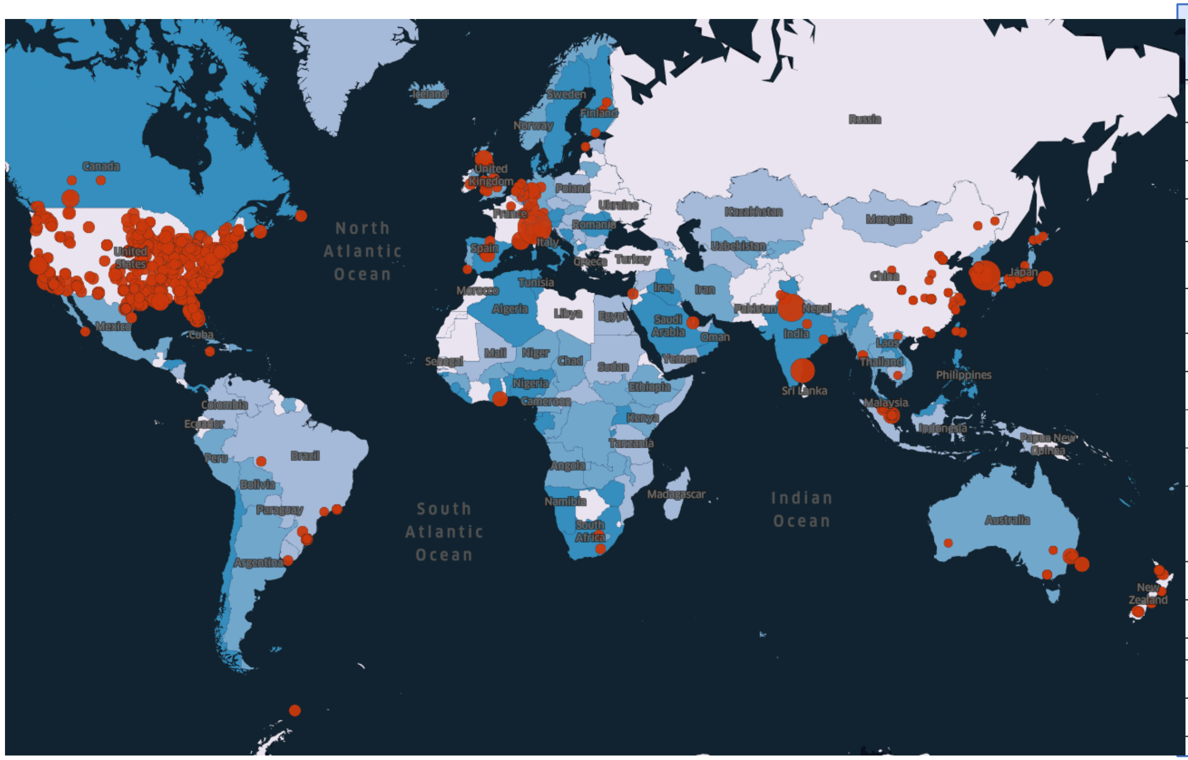
Viable SARS-CoV-2 in the air of a hospital room with COVID-19 patients in Florida

- Air samples were collected in the room of 2 patients, 2 to 4.8 m away from the patients
- 1 was positive for SARS-CoV-2
- The genome sequence of SARS-CoV-2 strain was found in air samples
- Patients with respiratory symptoms of COVID-19 produce virus containing aerosols
- these aerosols may transmit of the virus.



Lednicky et al (2020) https://doi.org/10.1101/2020.08.03.20167395

Superspreading Event Tracking



https://superspreadingdatabase.github.io/bubble-map-timeline.html

Code	Country	City/Region	Lat	Long	Setting1	Description	Indoor / Outdoor	Cases	Index Date
ITA7	Italy	Milan, Italy	45.463194	9.174297	Sports: Audience	Soccer game attendance	Indoor / Outdoor	7000	19/02/2020
KOR8	South Korea	Daegu, South Korea	35.813435	128.646341	Religious	The Shincheonenji church cluster	Indoor	5016	12/02/2020
IND5	India	Delhi, India	28.598	77.196	Religious	Tablighi Jamaat events, multiple days + events	Indoor	4000	15/03/2020
IND4	India	Koyambedu Market East Road, Virrugambakkam, Koyambedu,	13.066	80.195	Market	Vegetable market	Indoor / Outdoor	2760	22/04/2020
FRA2	France	Mulhouse, France	49.230	7.324	Religious		Indoor	2500	18/02/2020
USA917	United States	Marion Correctional Institution — Marion, Ohio	40.616604	-83.069296	Prison		Indoor	2,439	15/03/2020
USA19	United States	Pickaway Correctional Institution — Scioto Township, Ohio	41.172402	-81.450184	Prison		Indoor	1,791	15/03/2020
USA20	United States	Trousdale Turner Correctional Center — Hartsville, Tenn.	39.26755	-85.69804	Prison		Indoor	1,315	15/03/2020
IDO	Indonesia	Bandung, West Java, Indonesia	-6.920	107.600	Army base	Indonesian Army Officer Candidate School	Indoor / Outdoor	1280	06/07/2020
USA21	United States	Lompoc Prison Complex — Lompoc, Calif.	34.629464	-120.336594	Prison		Indoor	1,114	15/03/2020
USA911	United States	San Quentin, California, United States	37.938	-122.4000	Prison	San Quentin State Prison	Indoor	1105	15/06/2020
USA22	United States	Smithfield Foods pork processing facility — Sioux Falls, S.D.	43.546358	-96.69063	Food processing		Indoor	1,098	15/03/2020
FRA5	France	Mediterranean Sea, France	42.920000	5.516572	Ship: Military	Navy ship	Indoor	1081	01/04/2020
USA23	United States	Cook County jail — Chicago, Ill.	41.88531	-87.62213	Prison		Indoor	1,057	15/03/2020
USA24	United States	Chuckawalla Valley State Prison — Blythe, Calif.	33.736458	-114.687973	Prison		Indoor	1,031	15/03/2020
USA25	United States	Tyson Foods meatpacking plant — Waterloo, Iowa	42.441117	-92.339209	Meat Processing		Indoor	1,031	15/03/2020
USA26	United States	Cummins Unit prison — Grady, Ark.	37.432335	-76.601616	Prison		Indoor	1,028	15/03/2020

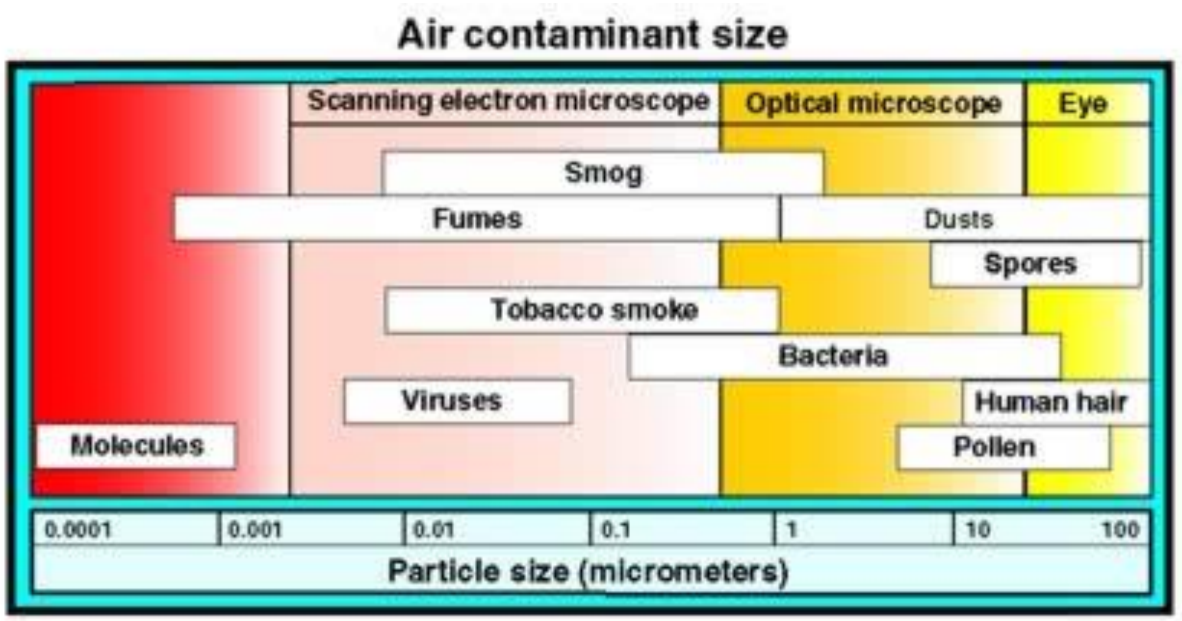
Swinkels, K. (2020). COVID-19 Superspreading Events Around the World [Google Sheet]. Retrieved from https://docs.google.com/spreadsheets/d/1c9jwMyT1lw2P0d6SDTno6nHLGMtpheO9xJyGHgdBoco/edit?usp=sharing

How does Microorganisms Spread?

- It can spread from person-to-person:
  1. People in close contact
  2. Respiratory droplets via coughs, sneezes, etc.
  3. Touching surfaces of where the virus settled on
  4. Significant portion of people do not feel any symptoms, can act as virus carriers (Corona)

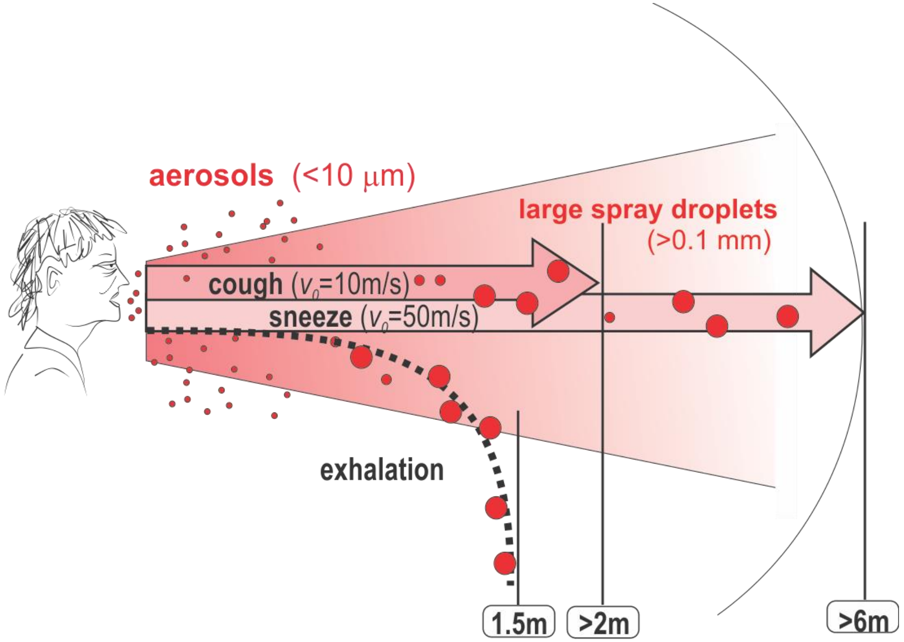
Microorganisms

- Found in outdoor air and enter a building through the HVAC system.
- Carried in by building occupants.
- Some grow in various parts of the building.
- Most contaminants are larger than 1 micron in diameter.
- Symptoms:
  - Minor irritations.
  - Headaches.
  - Asthma.



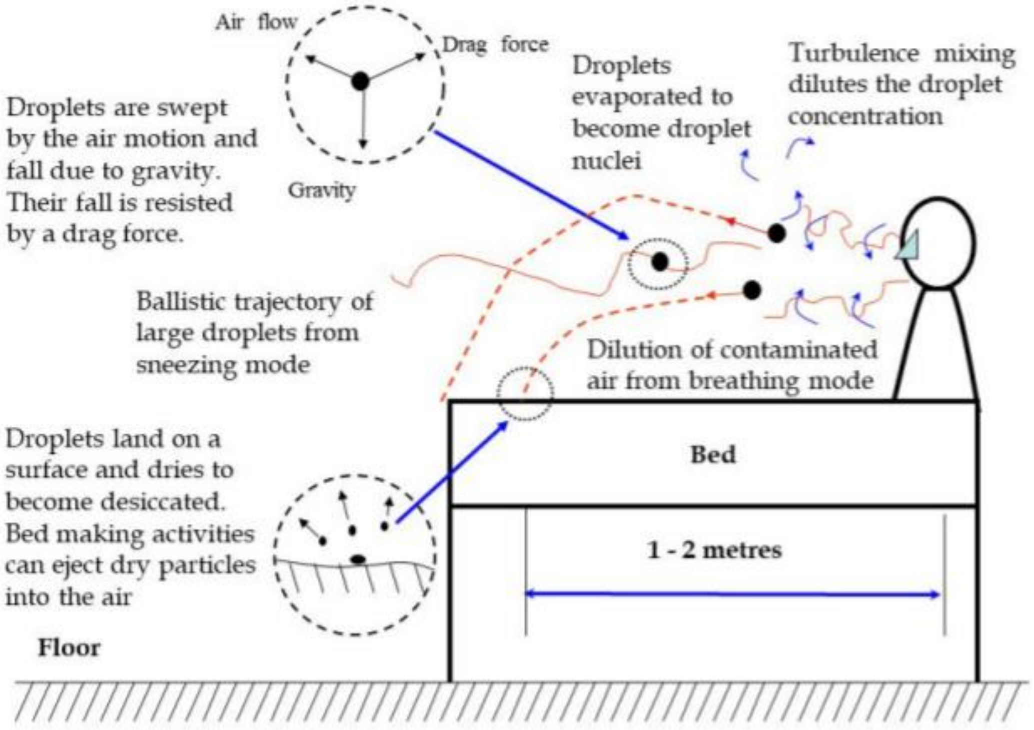
Why the Virus can be Airborne

- Droplets from coughs and sneezes are generated in different sizes:
  - Large Droplets: $100\ \mu m$ or larger tend to settle to the floor in a few seconds, usually drop within 1 to 2 m (3-6 ft).
    - However, if they are deployed at higher velocities (sneezes and coughs) they can go longer distances
  - Small Droplets (aerosols < 5 μm): Can last in the air for 1.5 hours $(3\ \mu m)$ to 41 hours $(0.5\ \mu m)$, can travel longer distance
  - Depending on the air distribution system, strong indoor air currents can spread aerosols



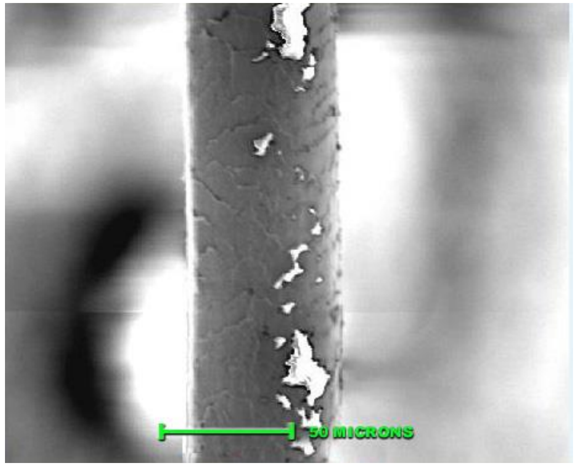
Airborne Transmission

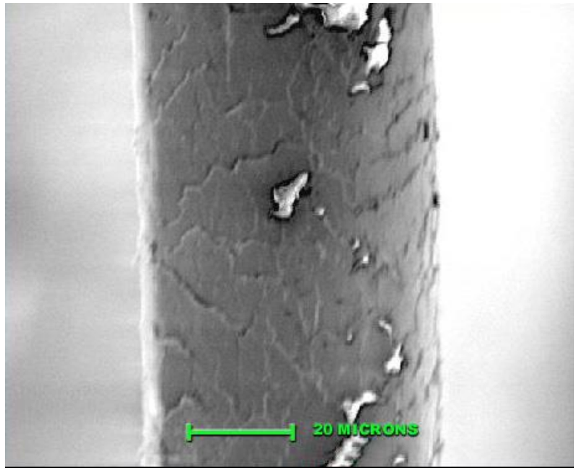
- Smaller aerosols can last for significant time in the air.
- Those aerosols can spread throughout a room or household if the HVAC system is poorly designed or installed
- Consequently, cross-infections can occur

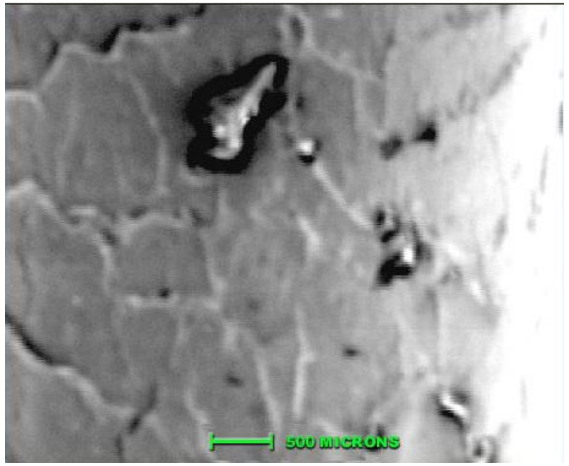


Particulate Contaminants

Human Hair	(70 - 100 microns)
Human Sneeze	(10 - 100 microns)
Pet Dander	(0.5 - 100 microns)
Pollen	(5 - 100 microns)
Spores from Plants	(6 - 100 microns)
Mold	(2 - 20 microns)
Smoke	(.01 - 1 micron)
Dust Mite Dropping	(0.5 – 1.5 microns)
Household Dust	(.05 - 100 microns)
Skin Flakes	(0.4 - 10 microns)
Bacteria	(0.35 - 10 microns)
Viruses	(0.1 microns)







Gaseous Contaminants

- Usually are combustion products such as:
    - Carbon Monoxide (CO).
    - Oxides of Nitrogen (NO_X).
    - Oxides of Sulfer (SO_X).
    - Carbon Dioxide (CO_2).
    - Tobacco Smoke Components
- *Irritant low concentration and can cause severe health effects in high concentration.*

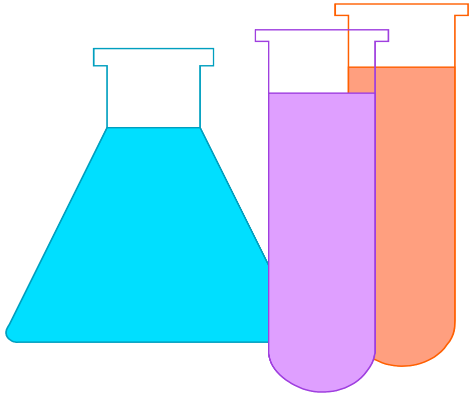
Levels of Gaseous Contaminants

- Carbon Dioxide CO_2 (350-1000 ppm)
- Carbon Monoxide CO (must not exceed 9 ppm)
- Nitrogen Dioxide NO_2 (must not exceed 0.05 ppm)
- Ozone O_3 (must not exceed 0.07 ppm)
- Sulphur dioxide SO_2 (must not exceed 0.03 ppm)
- Formaldehyde HCHO (must not exceed 7.3 ppb on an 8-hour period)

Vaporous Contaminants

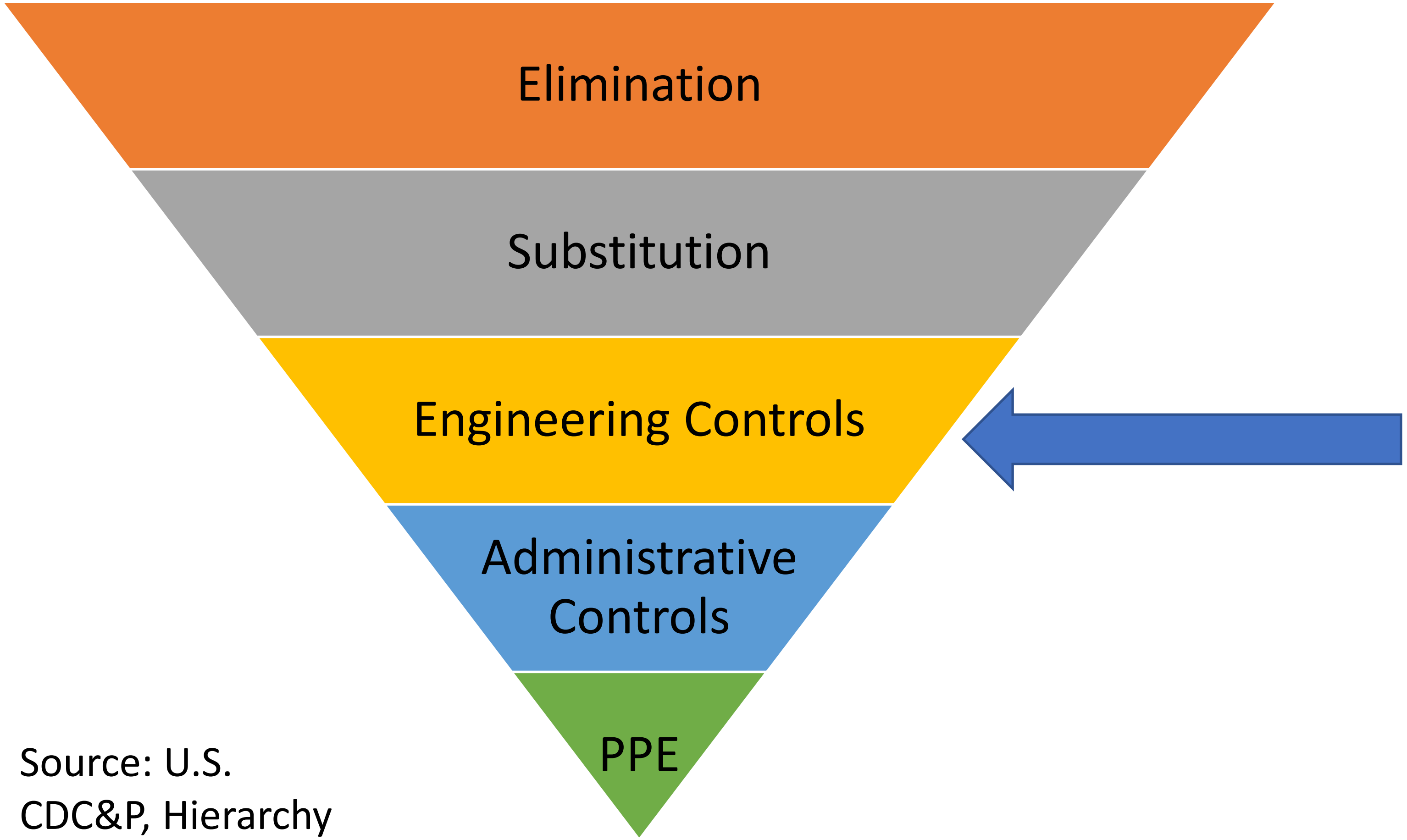
Usually are Volatile Organic Chemicals (VOCs)

- Resulted from evaporation and off-gassing:
  1. Carpet.
  2. Tile adhesives.
  3. Insulation
  4. Sweat from Humans and indoor pets



- Irritants to building occupants.
- May cause adverse health effects.
- Vaporous contaminants are smaller than 0.01 microns.
- E.g. Formaldehyde HCHO (must not exceed 7.3 ppb on an 8-hour period)

How to Improve the IAQ?



Elimination

Substitution

Engineering Controls

Administrative Controls

PPE

Engineering Controls can be used to reduce infections through the HVAC system

Source: U.S. CDC&P, Hierarchy of prevention

Engineering Controls

- Ventilation
- Filtration
- Air Distribution
- Disinfection
- Temperature and Humidity Controls

Ventilation

- Outdoor ventilation dilutes indoor contaminants and particles
- Effective, but energy intensive
- Increase in outdoor air requires significant increase in coil sizes
- This results in higher pressure drops through the coil, and energy consumption

% Ventilation Air	Coil Pressure Drop (ft H_20)	Total Capacity (Tons)
20	5.04	37
40	7.90	48.5
50	9.49	54.2
70	13.43	65.9
90	18.48	77.4

Source: https://www.retrofitmagazine.com/the-ashrae-epidemic-task-force-prepares-facilities-for-future-epidemics/

Impact of Ventilation Increase on the Coil

- Depending on the location, the sensible and latent heat can increase
- If you are in a location next to a seaside or with relatively high humidity (E.g. Dubai), the latent load on the coil will increase
- If you are in a dry area (E.g. Kuwait), the sensible coil load will increase

OA%	Load Increase %	Sensible Capacity of Total
20%	N/A	74%
50%	45%	57%
80%	90%	48%

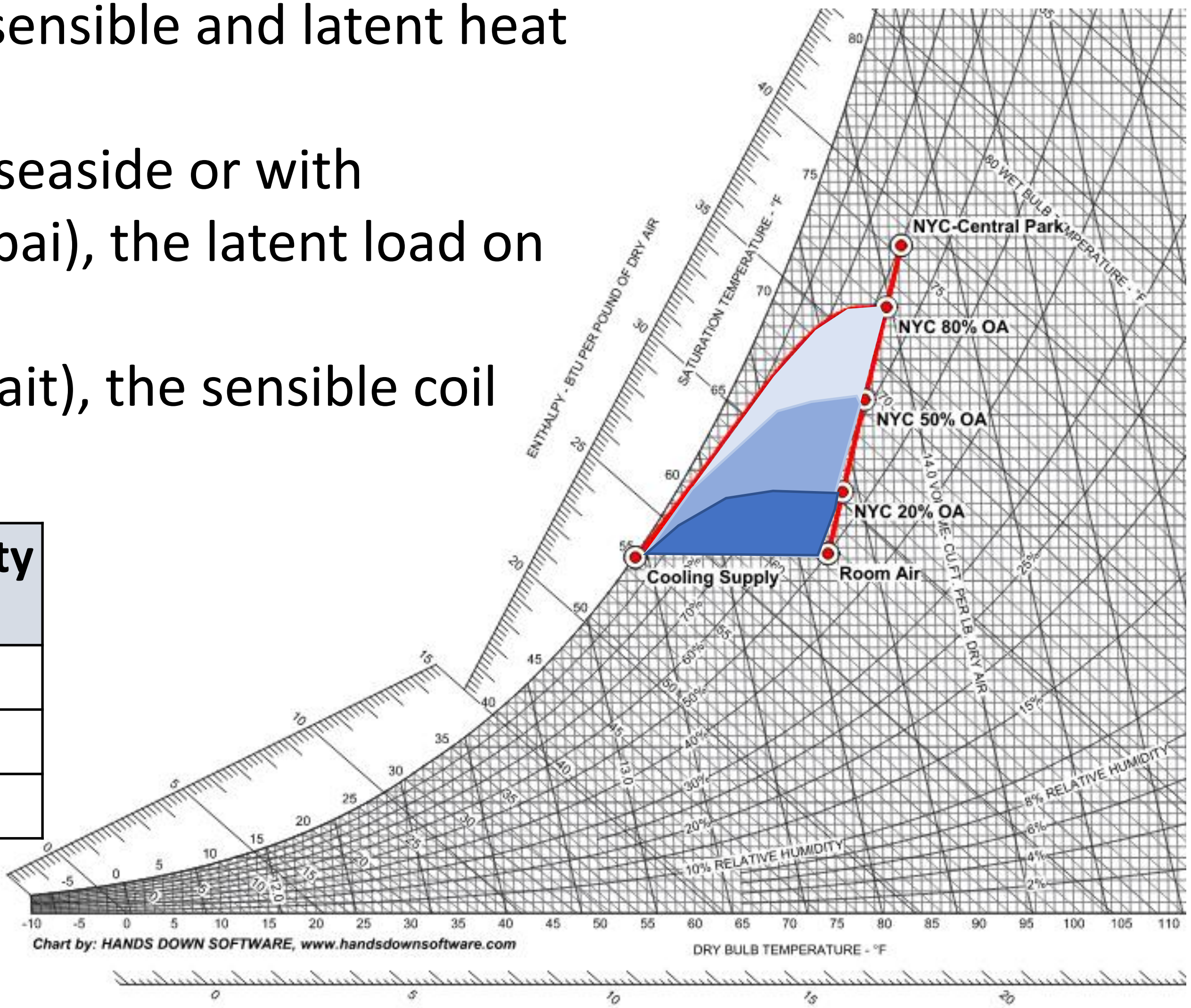
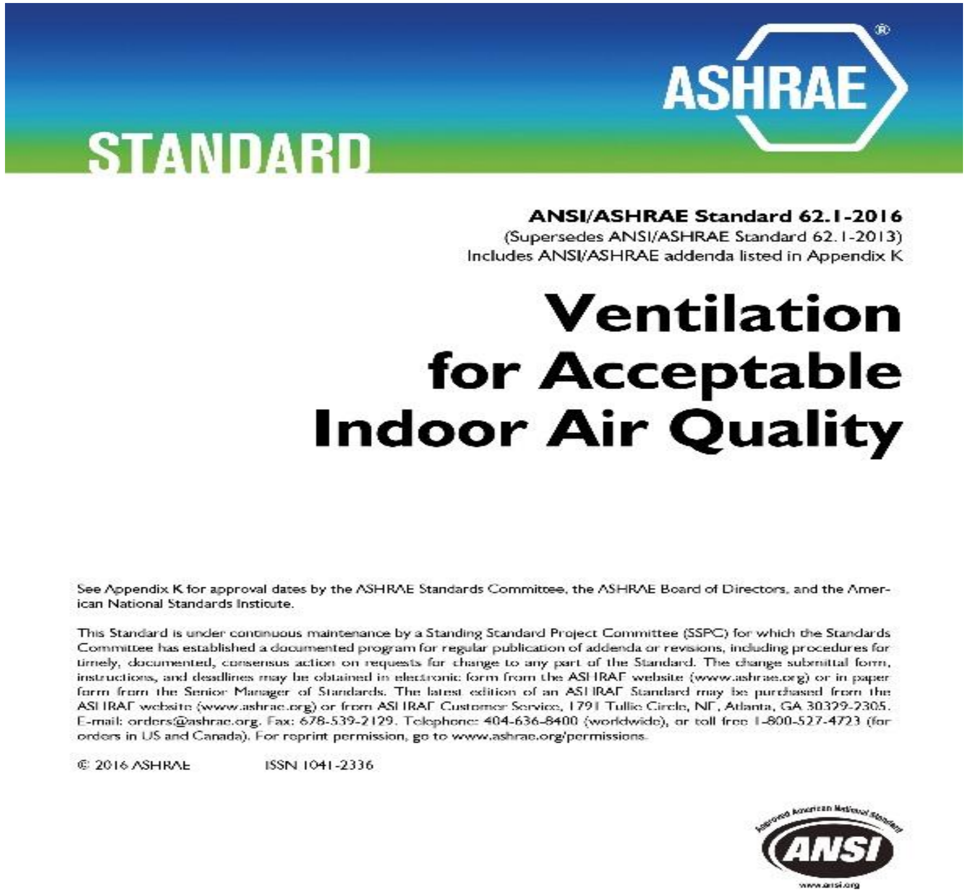


Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com

Commercial Building Ventilation Rates

- Why not use 100% OA?
  - ↑ Heating and cooling equipment size
  - ↑ Energy consumed
- Minimums dictated by local code
  - Most based on Standard 62.1



ANSI/ASHRAE Standard 62.1-2016
(Supersedes ANSI/ASHRAE Standard 62.1-2013)
Includes ANSI/ASHRAE addenda listed in Appendix K

Ventilation for Acceptable Indoor Air Quality

See Appendix K for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, and the American National Standards Institute.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE website (www.ashrae.org) or in paper form from the Senior Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 678-539-2129. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

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Commercial Buildings Ventilation

- Pollutants generated from two sources:
  - People
  - Building
- Dependent on space size and density of people

$$\mathbf{V = R_pP_z + R_aA_z}$$

R_p = Outdoor flow rate per person (CFM, L/s)
P_z = Number of people
R_a = Outdoor flow rate per area (CFM, L/s)
A_z = Floor area (ft^2, m^2)

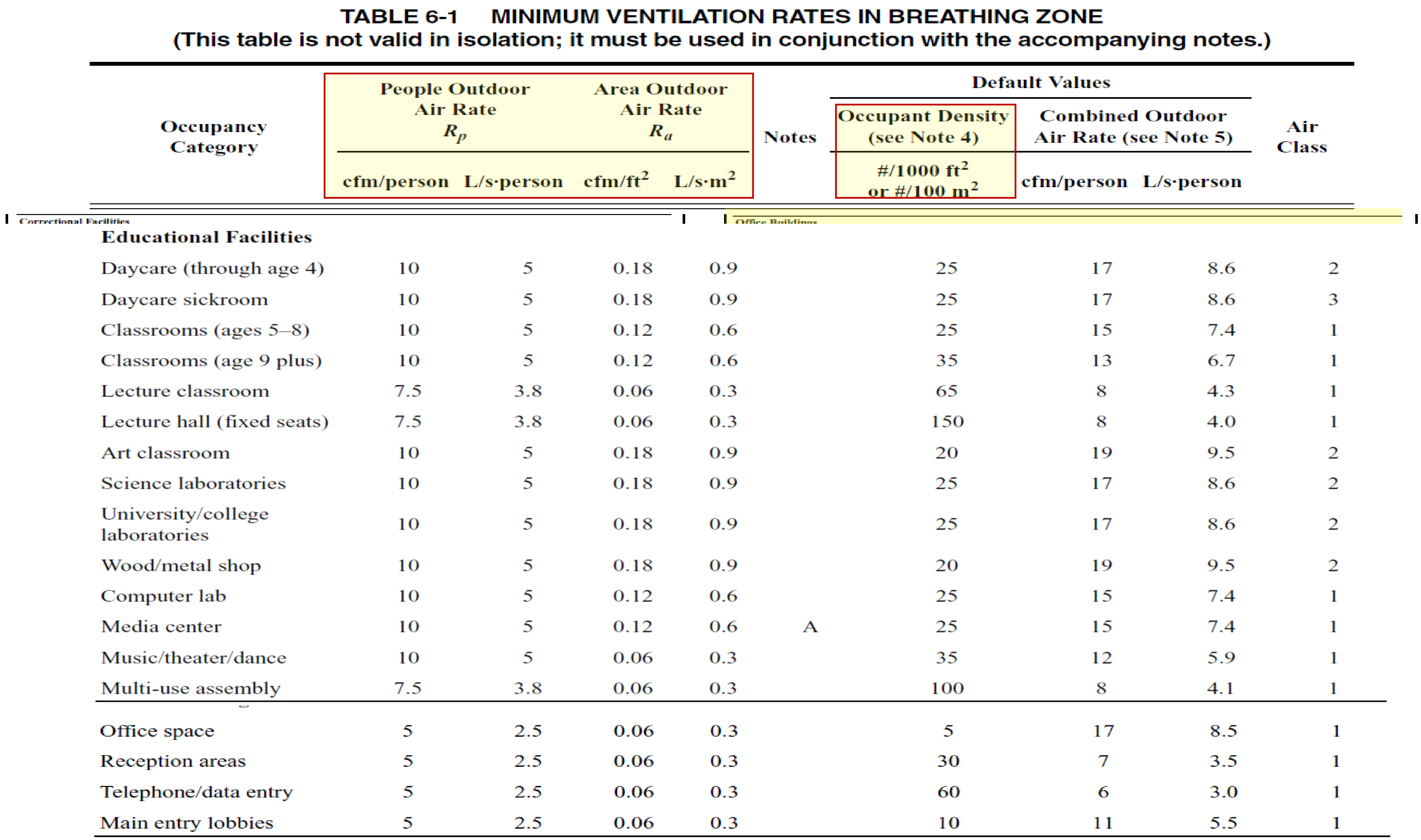


TABLE 6-1 MINIMUM VENTILATION RATES IN BREATHING ZONE

(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

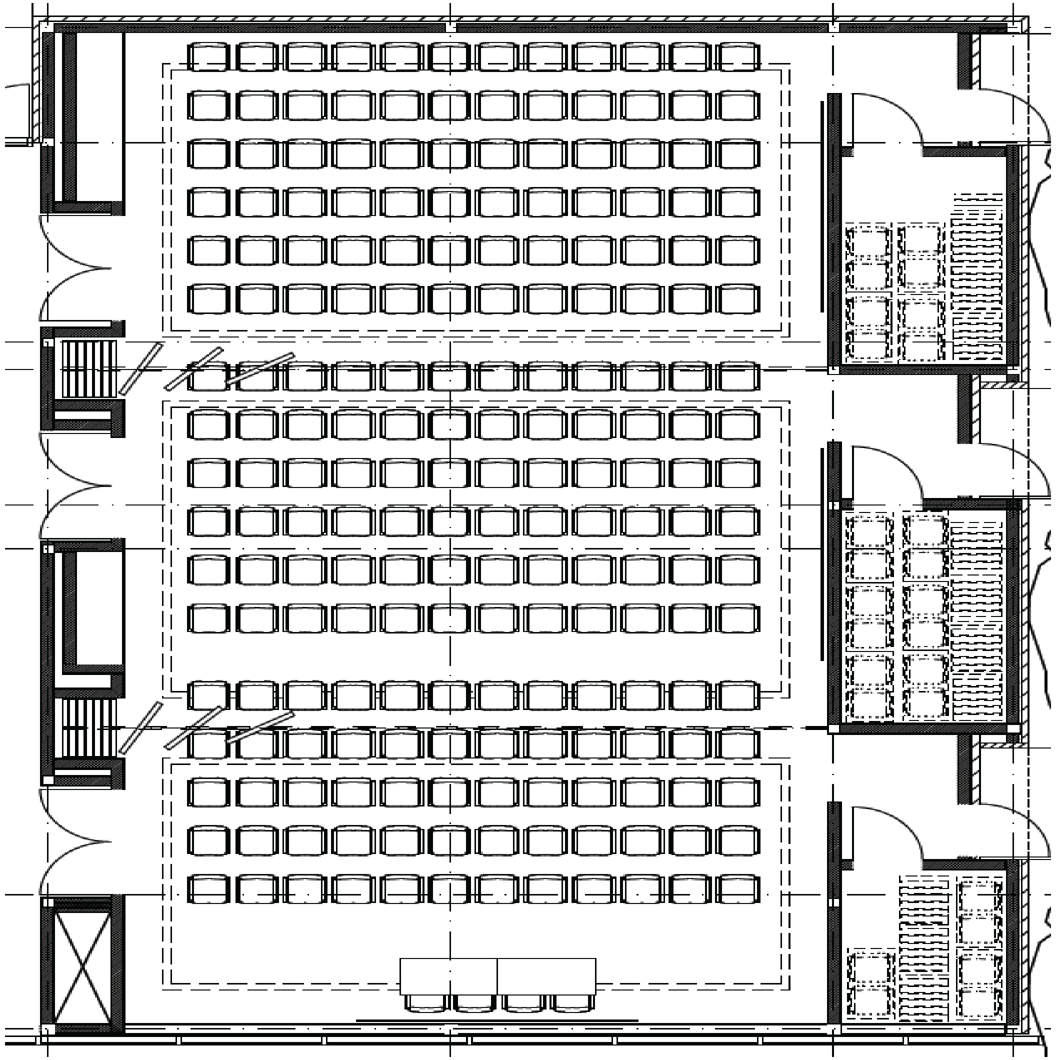
Correctional Facilities

Office Buildings

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Notes	Default Values			Air Class
						Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		
	cfm/person	L/s·person	cfm/ft²	L/s·m²		#/1000 ft² or #/100 m²	cfm/person	L/s·person	
Educational Facilities									
Daycare (through age 4)	10	5	0.18	0.9		25	17	8.6	2
Daycare sickroom	10	5	0.18	0.9		25	17	8.6	3
Classrooms (ages 5–8)	10	5	0.12	0.6		25	15	7.4	1
Classrooms (age 9 plus)	10	5	0.12	0.6		35	13	6.7	1
Lecture classroom	7.5	3.8	0.06	0.3		65	8	4.3	1
Lecture hall (fixed seats)	7.5	3.8	0.06	0.3		150	8	4.0	1
Art classroom	10	5	0.18	0.9		20	19	9.5	2
Science laboratories	10	5	0.18	0.9		25	17	8.6	2
University/college laboratories	10	5	0.18	0.9		25	17	8.6	2
Wood/metal shop	10	5	0.18	0.9		20	19	9.5	2
Computer lab	10	5	0.12	0.6		25	15	7.4	1
Media center	10	5	0.12	0.6	A	25	15	7.4	1
Music/theater/dance	10	5	0.06	0.3		35	12	5.9	1
Multi-use assembly	7.5	3.8	0.06	0.3		100	8	4.1	1
Office space	5	2.5	0.06	0.3		5	17	8.5	1
Reception areas	5	2.5	0.06	0.3		30	7	3.5	1
Telephone/data entry	5	2.5	0.06	0.3		60	6	3.0	1
Main entry lobbies	5	2.5	0.06	0.3		10	11	5.5	1

Ventilation Rate Example (Commercial)

- Multi-Use Assembly:
  - 62.1 Density Table:
  - 100 people/1000 ft^2
  - Area: 1,822 ft^2
  - 183 people
- Architectural Life Safety Plans:
  - 260 people
- Floor plan: 208 Chairs



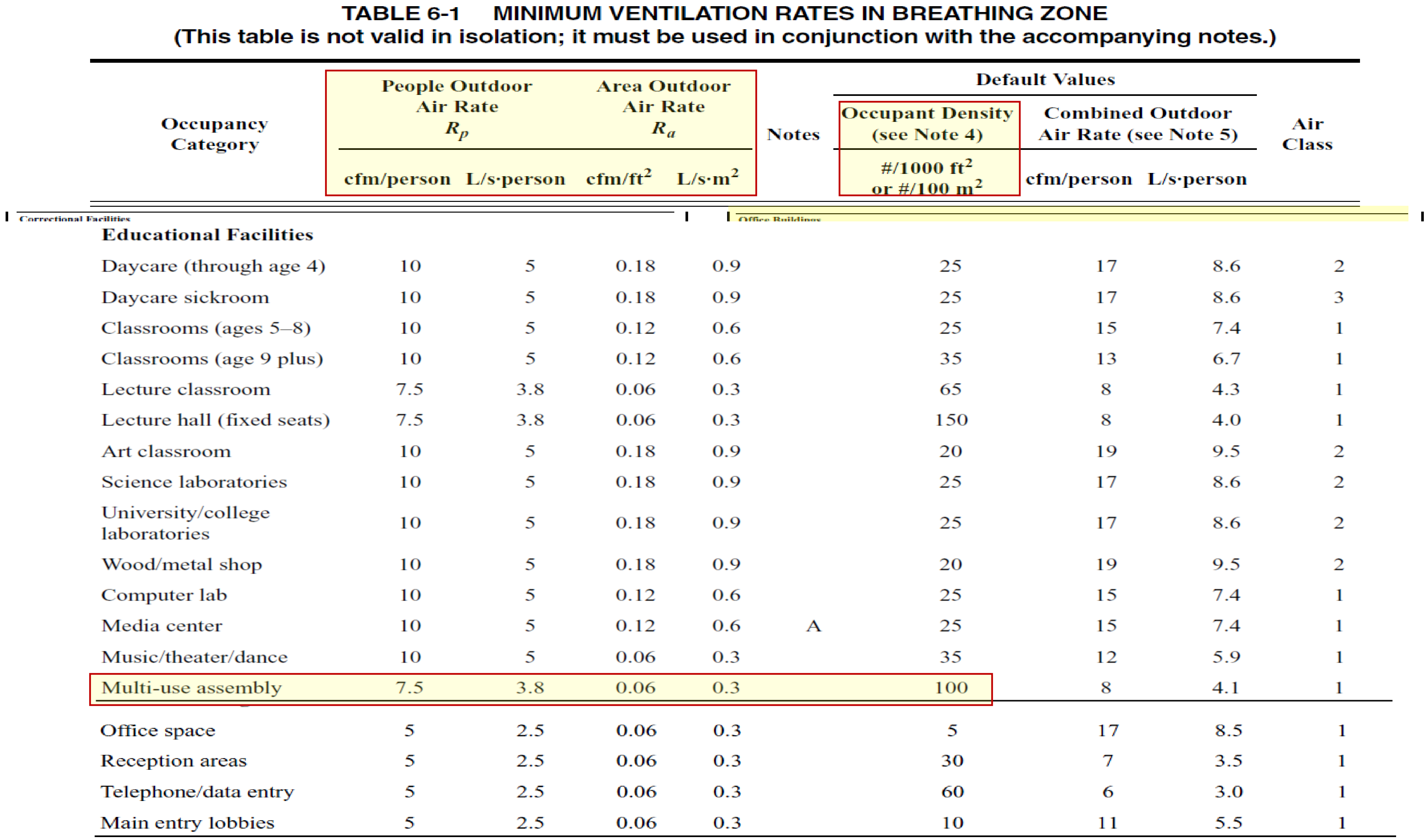


TABLE 6-1 MINIMUM VENTILATION RATES IN BREATHING ZONE

(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Notes	Default Values			Air Class
						Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		
	cfm/person	L/s·person	cfm/ft^2	L/s·m^2		#/1000 ft^2 or #/100 m^2	cfm/person	L/s·person	
Educational Facilities									
Daycare (through age 4)	10	5	0.18	0.9		25	17	8.6	2
Daycare sickroom	10	5	0.18	0.9		25	17	8.6	3
Classrooms (ages 5–8)	10	5	0.12	0.6		25	15	7.4	1
Classrooms (age 9 plus)	10	5	0.12	0.6		35	13	6.7	1
Lecture classroom	7.5	3.8	0.06	0.3		65	8	4.3	1
Lecture hall (fixed seats)	7.5	3.8	0.06	0.3		150	8	4.0	1
Art classroom	10	5	0.18	0.9		20	19	9.5	2
Science laboratories	10	5	0.18	0.9		25	17	8.6	2
University/college laboratories	10	5	0.18	0.9		25	17	8.6	2
Wood/metal shop	10	5	0.18	0.9		20	19	9.5	2
Computer lab	10	5	0.12	0.6		25	15	7.4	1
Media center	10	5	0.12	0.6	A	25	15	7.4	1
Music/theater/dance	10	5	0.06	0.3		35	12	5.9	1
Multi-use assembly	7.5	3.8	0.06	0.3		100	8	4.1	1
Office space	5	2.5	0.06	0.3		5	17	8.5	1
Reception areas	5	2.5	0.06	0.3		30	7	3.5	1
Telephone/data entry	5	2.5	0.06	0.3		60	6	3.0	1
Main entry lobbies	5	2.5	0.06	0.3		10	11	5.5	1

Ventilation Rate Example (Commercial)

$$\boxed{V = R_pP_z + R_aA_z}$$

$R_p = 7.5$ **CFM/person**

$P_z = 208$ **people**

$R_a = 0.06$ **CFM/ft^2**

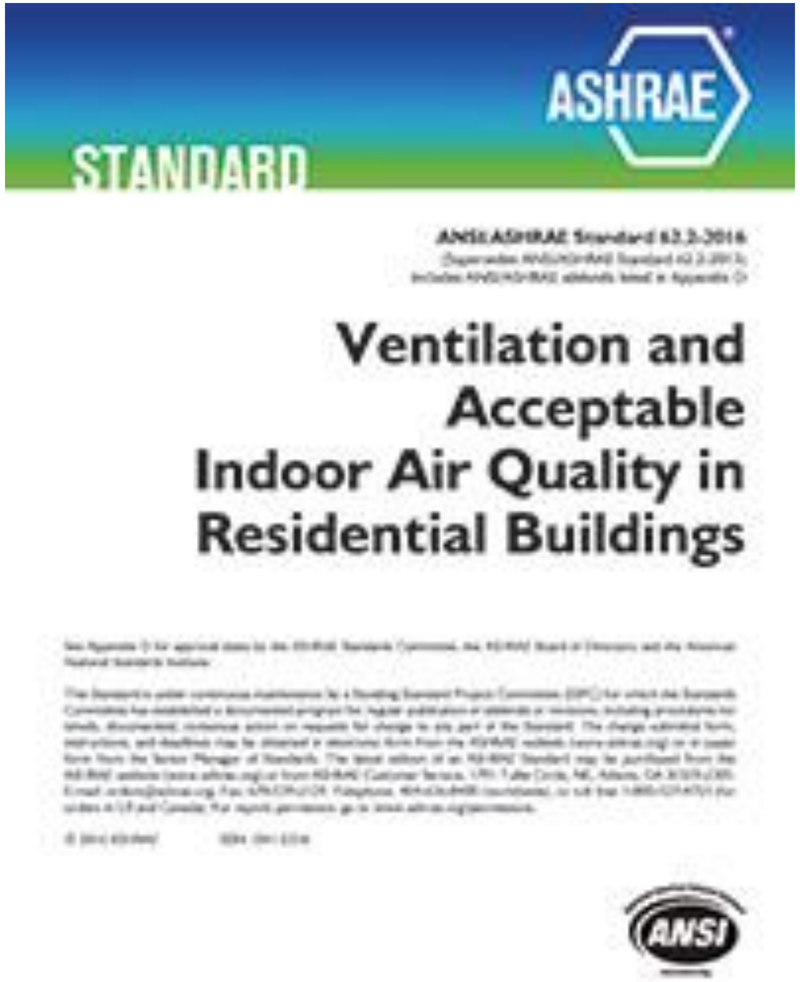
$A_z = 1{,}822$ **ft^2**

$$V = (7.5)(208)+(0.06)(1{,}822)$$

$$V = 1670\ \mathrm{CFM}_{OA}$$

Residential Building Ventilation Rates

- Why not use 100% OA?
  - ↑ Heating and cooling equipment size
  - ↑ Energy consumed, excessive electric bills
- Minimums dictated by local code
  - Most based on Standard 62.2



STANDARD

ASHRAE

ANSI/ASHRAE Standard 62.2-2016

Ventilation and Acceptable Indoor Air Quality in Residential Buildings

ANSI

Residential Ventilation Air Rates

- For residential buildings,
  1. ASHRAE Standard 62.2 is used
  2. The required ventilation flow rates is based on:
     a) Total floor area (A_{floor})
     b) Number of bedrooms (N_{br})
  3. Or the following equations can be used:
     a) $Q = 0.01\mathrm{A_{floor}} + 7.5(\mathrm{N_{br}} + 1)$ for I-P units or,
     b) $Q = 0.05\mathrm{A_{floor}} + 3.5(\mathrm{N_{br}} + 1)$ for SI units

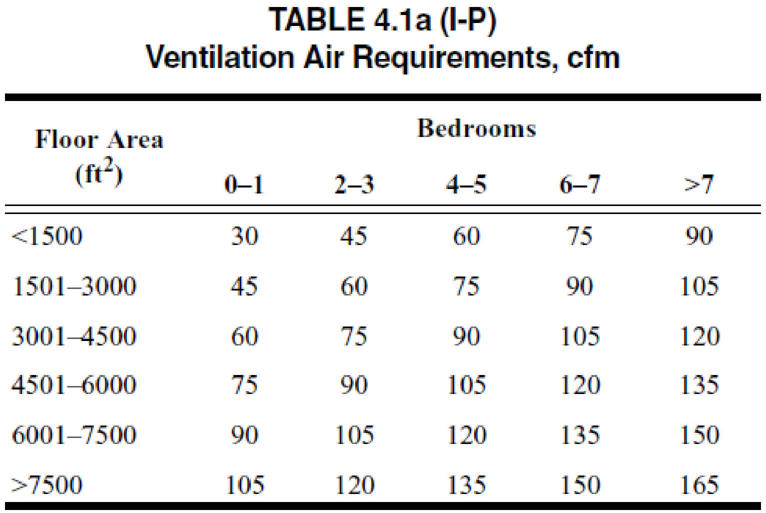


TABLE 4.1a (I-P)
Ventilation Air Requirements, cfm

Floor Area (ft^2)	Bedrooms				
	0–1	2–3	4–5	6–7	>7
<1500	30	45	60	75	90
1501–3000	45	60	75	90	105
3001–4500	60	75	90	105	120
4501–6000	75	90	105	120	135
6001–7500	90	105	120	135	150
>7500	105	120	135	150	165

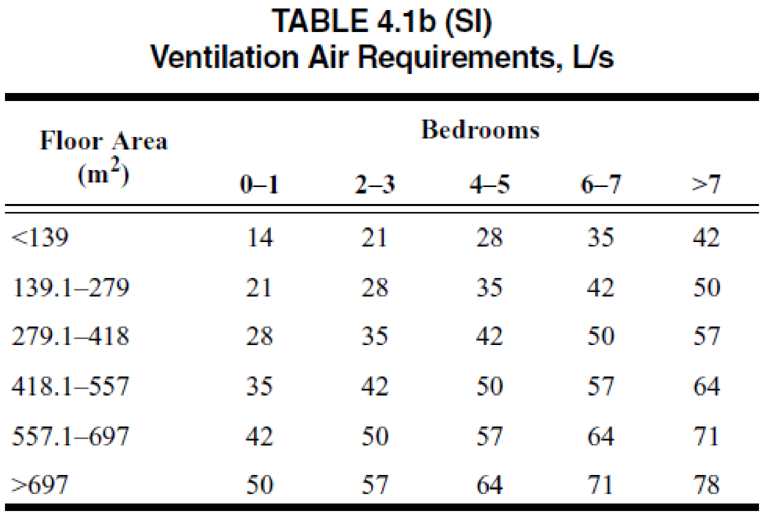


TABLE 4.1b (SI)
Ventilation Air Requirements, L/s

Floor Area (m^2)	Bedrooms				
	0–1	2–3	4–5	6–7	>7
<139	14	21	28	35	42
139.1–279	21	28	35	42	50
279.1–418	28	35	42	50	57
418.1–557	35	42	50	57	64
557.1–697	42	50	57	64	71
>697	50	57	64	71	78

Ventilation Rates in Healthcare Facilities

- Hospitals have their own recommended Ventilation Rates
- ASHRAE Standard 170 sets these rates in Air Changes per Hour (ACH)
- Rate outdoor air replaces indoor air.
- $\boldsymbol{ACH} = \boldsymbol{CFM} \times \dfrac{60}{(Area\ x\ Height)}$

STANDARD

ANSI/ASHRAE/ASHE Standard 170-2008

Ventilation of
Health Care Facilities

Ventilation Rates in Healthcare Facilities

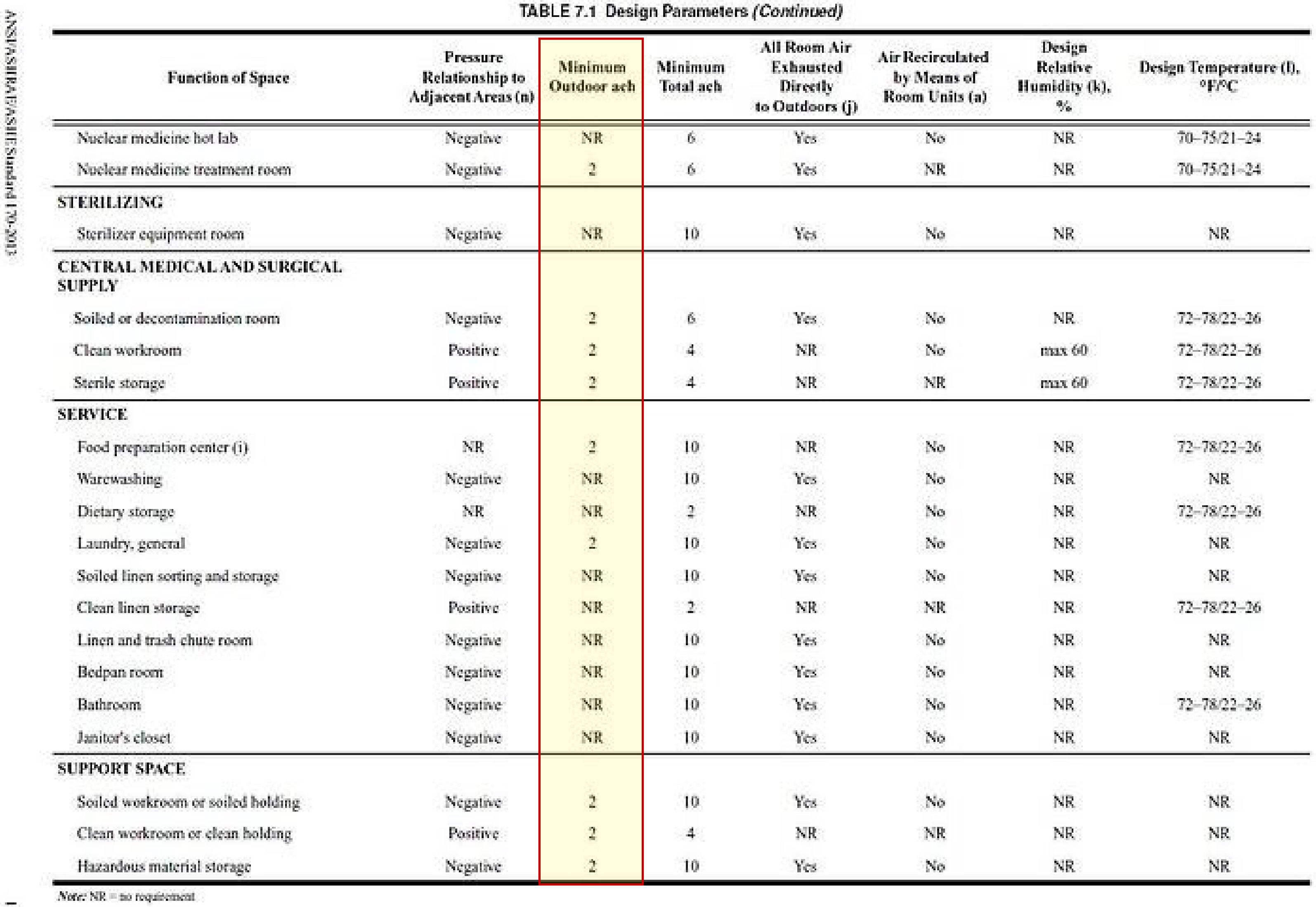


TABLE 7.1 Design Parameters *(Continued)*

Function of Space	Pressure Relationship to Adjacent Areas (n)	Minimum Outdoor ach	Minimum Total ach	All Room Air Exhausted Directly to Outdoors (j)	Air Recirculated by Means of Room Units (a)	Design Relative Humidity (k), %	Design Temperature (l), °F/°C
Nuclear medicine hot lab	Negative	NR	6	Yes	No	NR	70–75/21–24
Nuclear medicine treatment room	Negative	2	6	Yes	NR	NR	70–75/21–24
STERILIZING							
Sterilizer equipment room	Negative	NR	10	Yes	No	NR	NR
CENTRAL MEDICAL AND SURGICAL SUPPLY							
Soiled or decontamination room	Negative	2	6	Yes	No	NR	72–78/22–26
Clean workroom	Positive	2	4	NR	No	max 60	72–78/22–26
Sterile storage	Positive	2	4	NR	NR	max 60	72–78/22–26
SERVICE							
Food preparation center (i)	NR	2	10	NR	No	NR	72–78/22–26
Warewashing	Negative	NR	10	Yes	No	NR	NR
Dietary storage	NR	NR	2	NR	No	NR	72–78/22–26
Laundry, general	Negative	2	10	Yes	No	NR	NR
Soiled linen sorting and storage	Negative	NR	10	Yes	No	NR	NR
Clean linen storage	Positive	NR	2	NR	NR	NR	72–78/22–26
Linen and trash chute room	Negative	NR	10	Yes	No	NR	NR
Bedpan room	Negative	NR	10	Yes	No	NR	NR
Bathroom	Negative	NR	10	Yes	No	NR	72–78/22–26
Janitor's closet	Negative	NR	10	Yes	No	NR	NR
SUPPORT SPACE							
Soiled workroom or soiled holding	Negative	2	10	Yes	No	NR	NR
Clean workroom or clean holding	Positive	2	4	NR	NR	NR	NR
Hazardous material storage	Negative	2	10	Yes	No	NR	NR

Note: NR = no requirement

Example: ACH for Operating Room

- Consider an Operating Room (OR), with width of 20 ft, length of 15 ft, and a height of 10 ft.
- Calculate the minimum required ventilation rate in CFM.
- $\boldsymbol{ACH = CFM} \times \frac{60}{(Area \times Height)}$
- So $CFM = ACH \times \frac{(Area \times Height)}{60}$
- $CFM = 4 \times \frac{20 \times 15 \times 10}{60} = 200\ CFM$

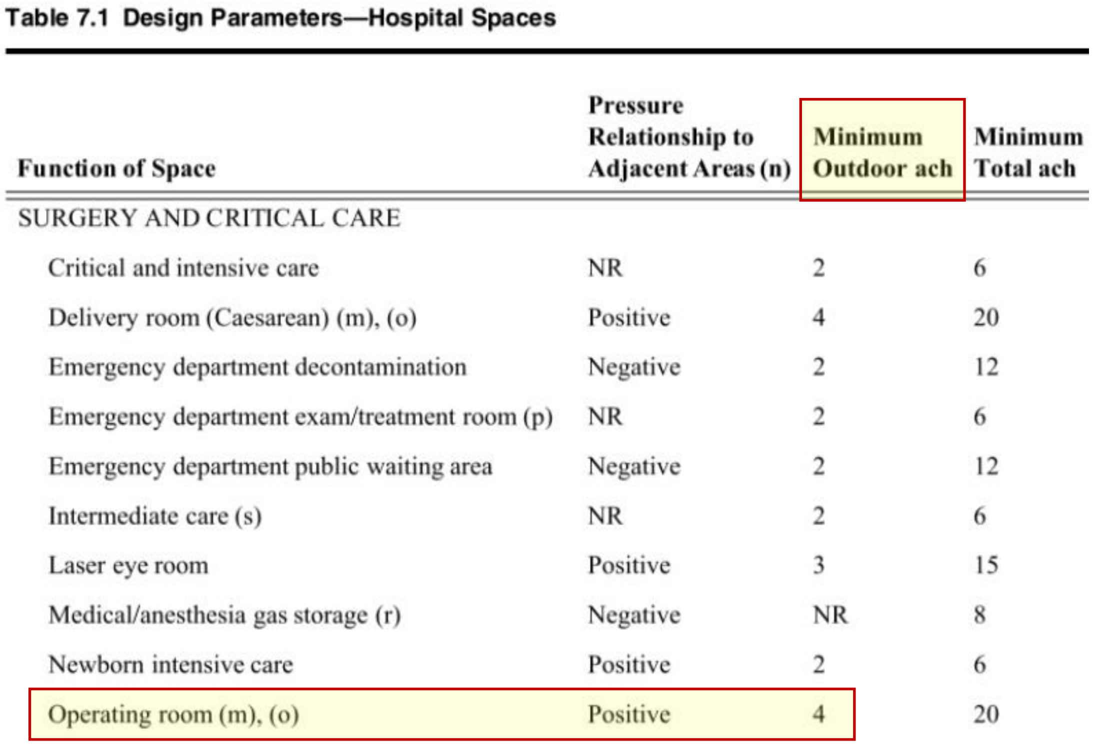


Table 7.1 Design Parameters—Hospital Spaces

Function of Space	Pressure Relationship to Adjacent Areas (n)	Minimum Outdoor ach	Minimum Total ach
SURGERY AND CRITICAL CARE			
Critical and intensive care	NR	2	6
Delivery room (Caesarean) (m), (o)	Positive	4	20
Emergency department decontamination	Negative	2	12
Emergency department exam/treatment room (p)	NR	2	6
Emergency department public waiting area	Negative	2	12
Intermediate care (s)	NR	2	6
Laser eye room	Positive	3	15
Medical/anesthesia gas storage (r)	Negative	NR	8
Newborn intensive care	Positive	2	6
Operating room (m), (o)	Positive	4	20

Types of Ventilation

- Infiltration
- Natural Ventilation
- Mechanical Ventilation

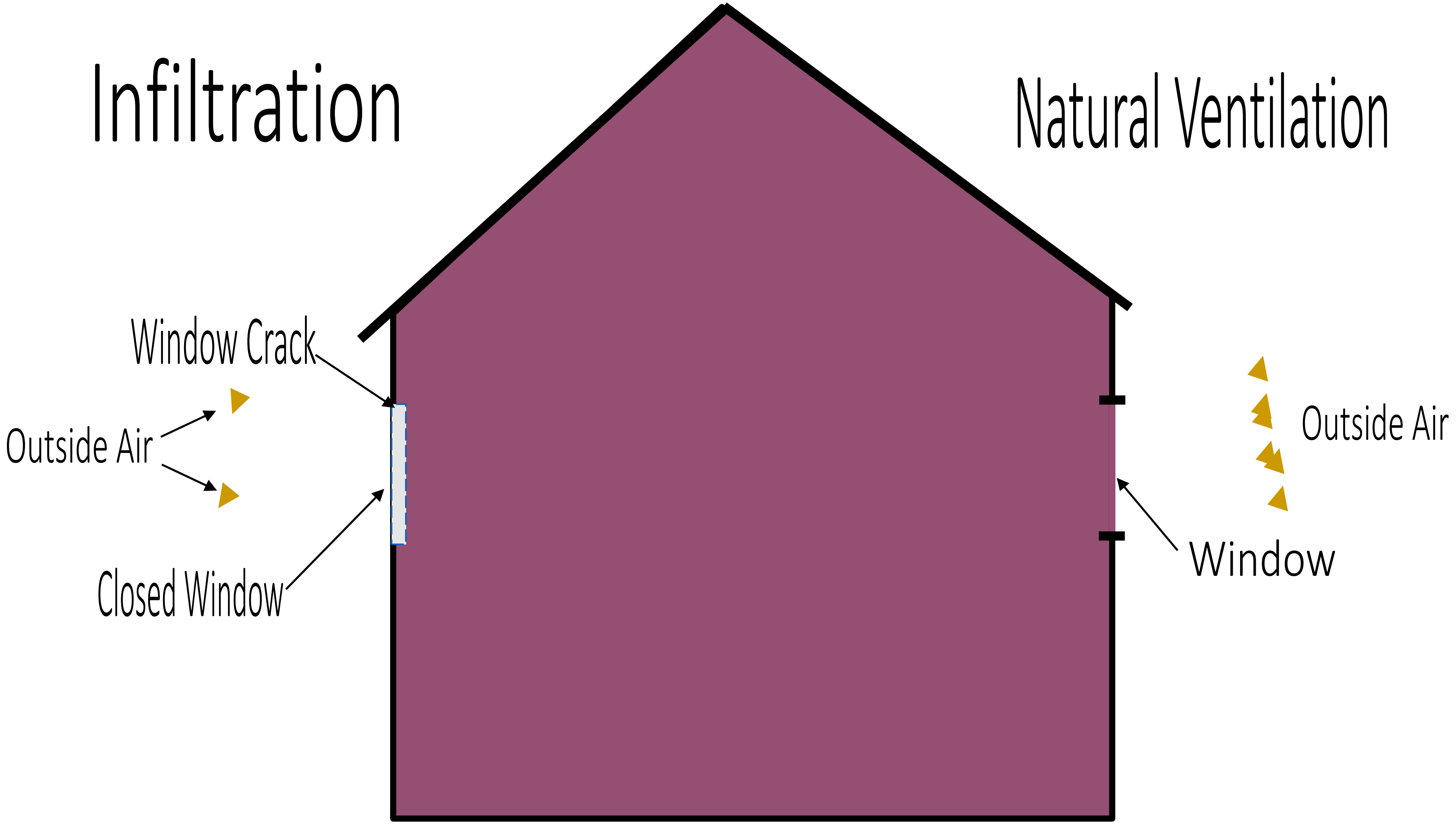
Infiltration

- Outdoor air flows into the house through openings, joints, and cracks in walls, floors, and ceilings, and around windows and doors.
- Pressure differences between the indoors and outdoors caused by winds.
- By indoor-outdoor temperature differences and HVAC systems.

Natural Ventilation

- Air coming in by the indoor occupants intentionally through:
  - doors,
  - windows,
  - other intentional openings in the building

Infiltration & Natural Ventilation

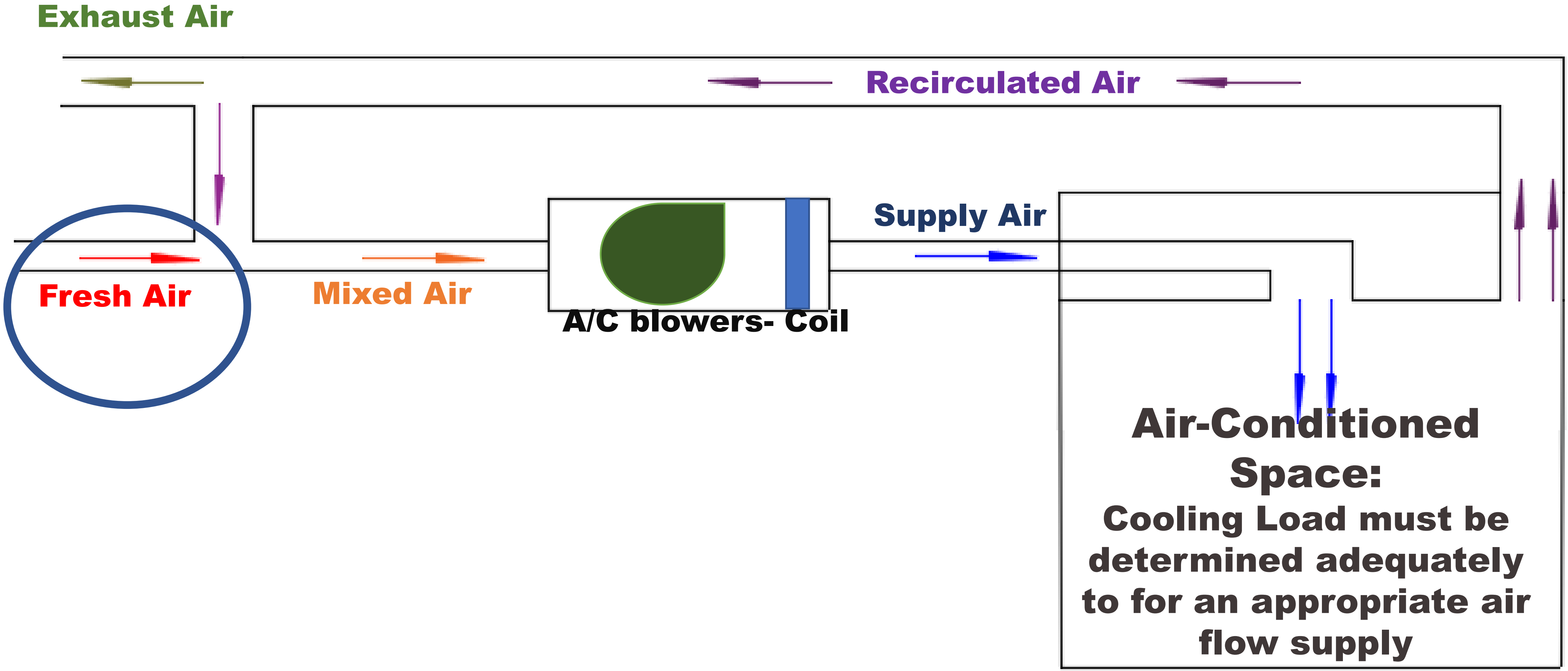


Mechanical Ventilation

- **Constant Volume System**
  1. Provides a constant air flow with the ability of varying temperature to meet the cooling and heating requirements.
  2. Residential houses.

- **Variable Air Volume**
  1. VAV conditions the air supplied to a constant temperature and humidity.
  2. Ensures thermal comfort by varying the air flow to the occupied space.
  3. Office buildings.

Mechanical Ventilation



Exhaust Air

Recirculated Air

Supply Air

Fresh Air

Mixed Air

A/C blowers- Coil

Air-Conditioned Space:

Cooling Load must be determined adequately to for an appropriate air flow supply

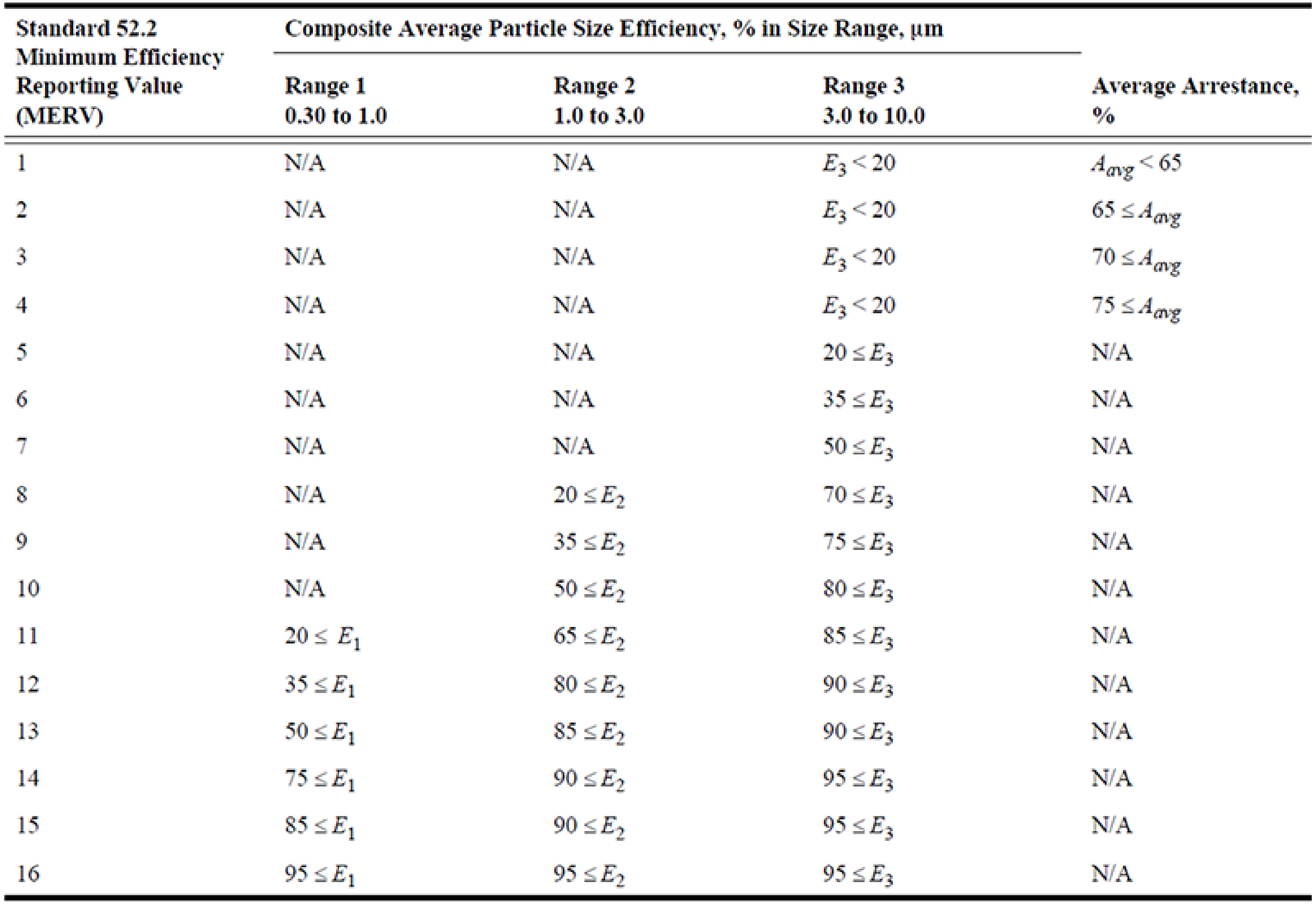
Filtration

- Filters can contribute to reducing indoor pollutants
- Filters with higher Minimum Efficiency Reporting Value (MERV) tend to remove finer particles

MERV 5-8 filters
Removes
Coarse particles

MERV 13-16 filters
Removes fine and
coarse particles at
higher efficiencies

MERV Rates



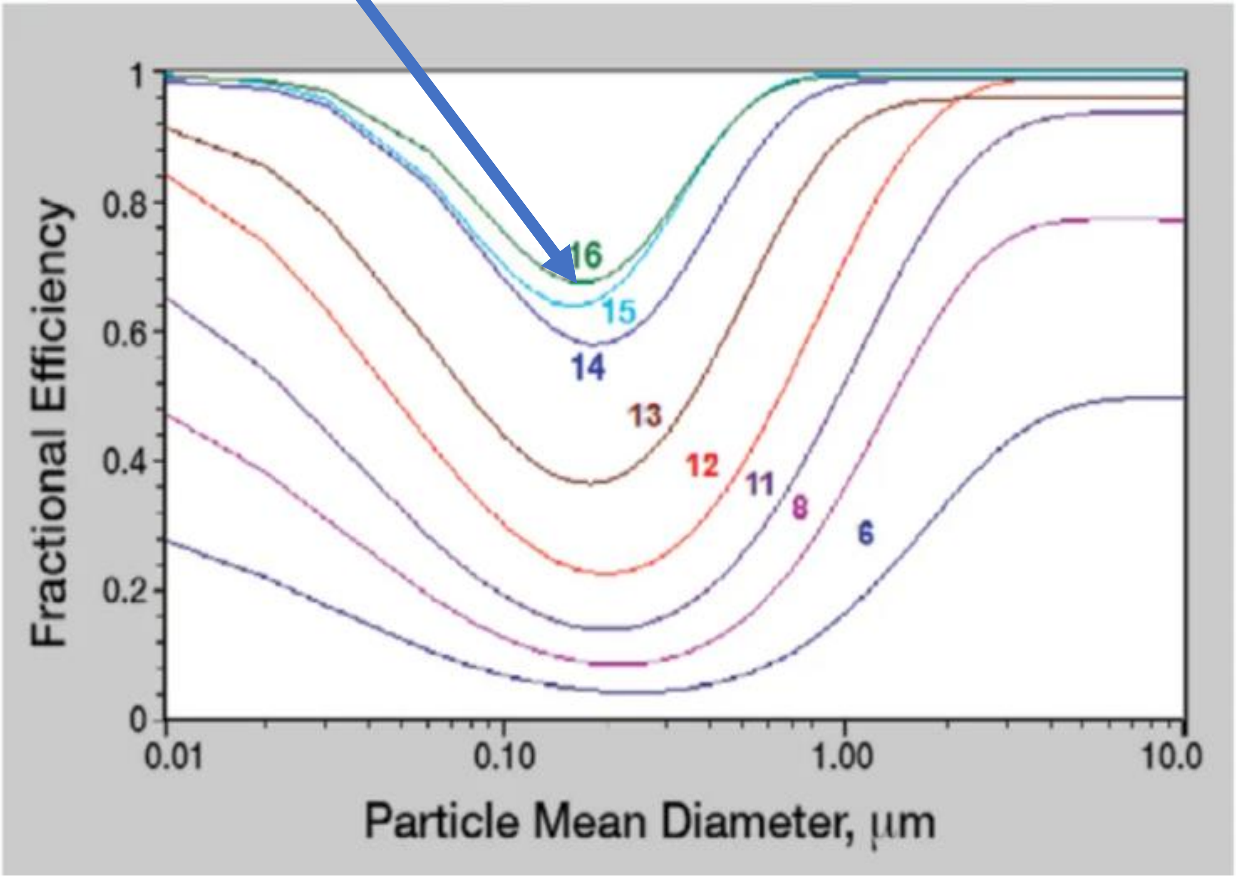
Standard 52.2 Minimum Efficiency Reporting Value (MERV)	Composite Average Particle Size Efficiency, % in Size Range, µm			Average Arrestance, %
	Range 1 0.30 to 1.0	Range 2 1.0 to 3.0	Range 3 3.0 to 10.0	
1	N/A	N/A	$E_3 < 20$	$A_{avg} < 65$
2	N/A	N/A	$E_3 < 20$	$65 \le A_{avg}$
3	N/A	N/A	$E_3 < 20$	$70 \le A_{avg}$
4	N/A	N/A	$E_3 < 20$	$75 \le A_{avg}$
5	N/A	N/A	$20 \le E_3$	N/A
6	N/A	N/A	$35 \le E_3$	N/A
7	N/A	N/A	$50 \le E_3$	N/A
8	N/A	$20 \le E_2$	$70 \le E_3$	N/A
9	N/A	$35 \le E_2$	$75 \le E_3$	N/A
10	N/A	$50 \le E_2$	$80 \le E_3$	N/A
11	$20 \le E_1$	$65 \le E_2$	$85 \le E_3$	N/A
12	$35 \le E_1$	$80 \le E_2$	$90 \le E_3$	N/A
13	$50 \le E_1$	$85 \le E_2$	$90 \le E_3$	N/A
14	$75 \le E_1$	$90 \le E_2$	$95 \le E_3$	N/A
15	$85 \le E_1$	$90 \le E_2$	$95 \le E_3$	N/A
16	$95 \le E_1$	$95 \le E_2$	$95 \le E_3$	N/A

Sources: ASHRAE Standard 52.2 - 2017

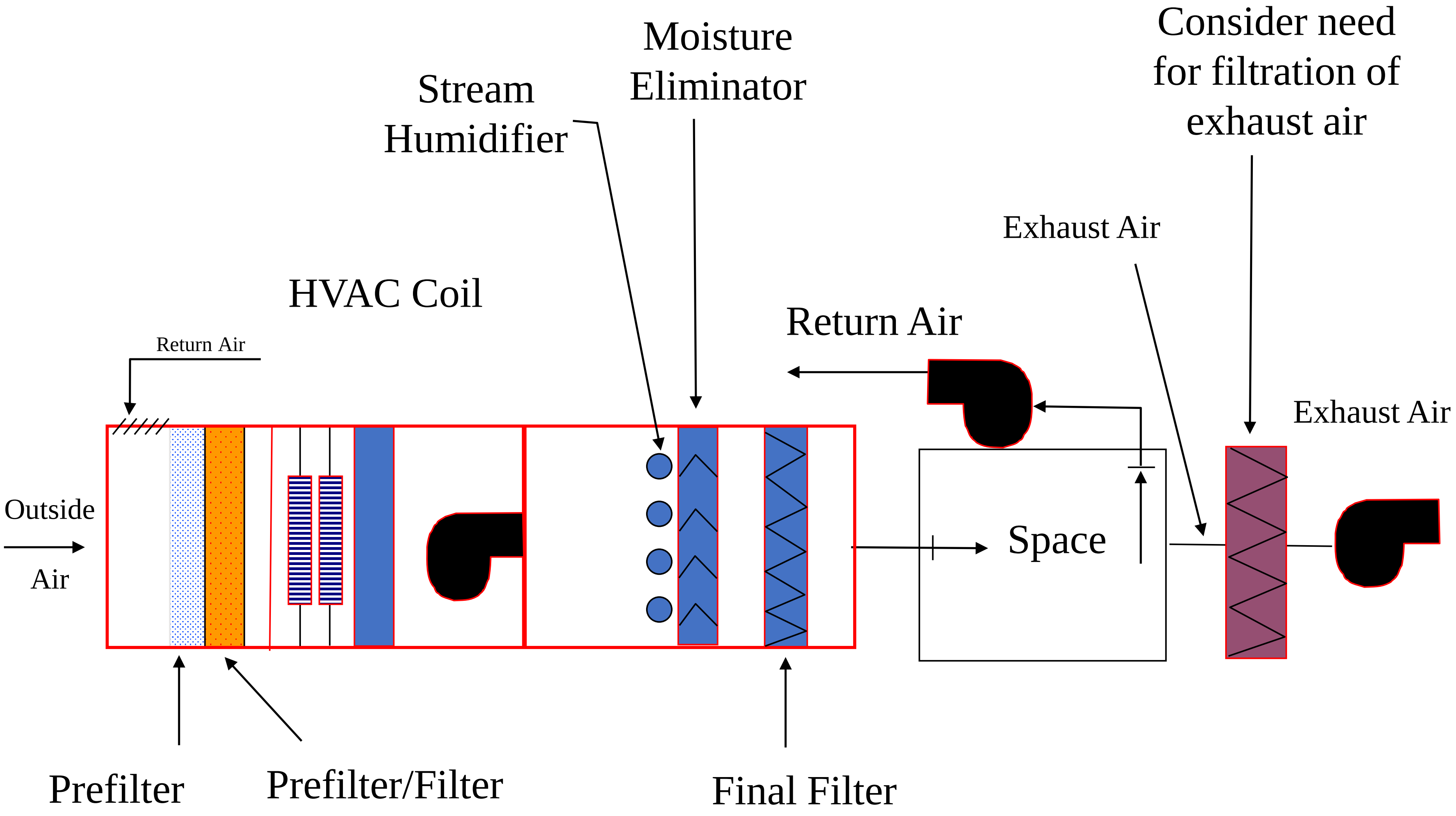
Filtration

- At higher MERV ratings, more particles can be removed
- Fractional efficiency is the percentage of particles of a certain size that would be stopped and retained by filter to the total particles.
- Particle will not be removed 100%
- Reduction of particles, reduces the risks of cross infections

Most Penetrating particle size through a filter usually between 0.1-0.3 μm

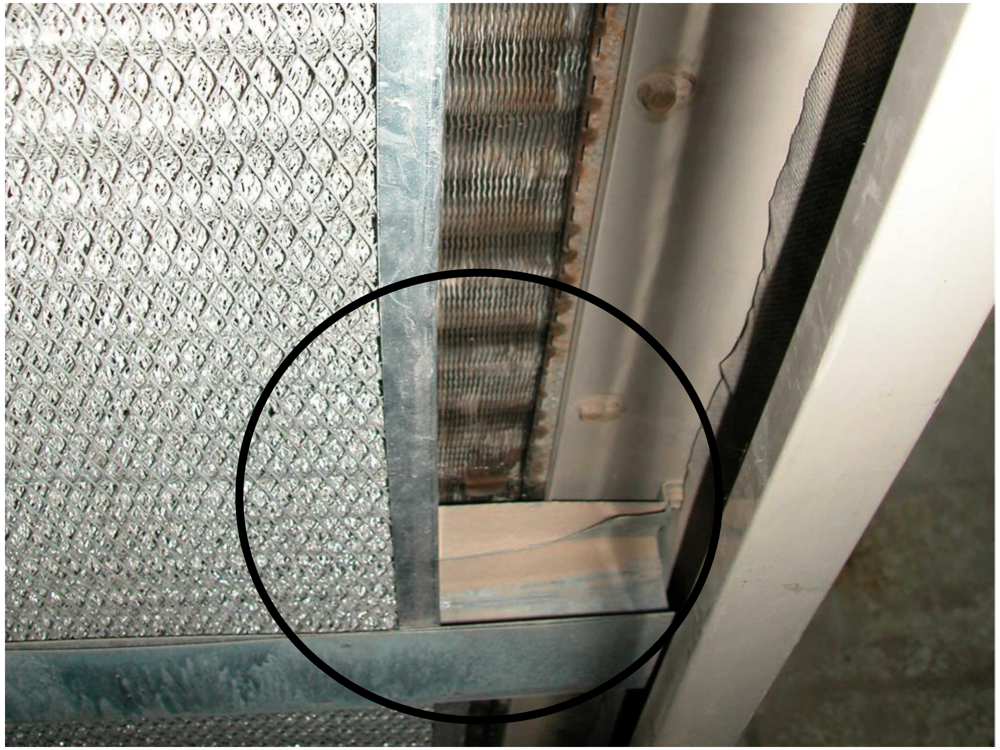


Typical Filter Application



Maintenance

- Appropriate air filter selection.
- Proper HVAC maintenance.
- Proper Humidification and dehumidification maintenance.
- Appropriate filter selection.
- Avoid accumulations of water.
- Visual inspection.
- Eliminate filter bypass (Sealing tape/Clamps).



Filtration Bypass

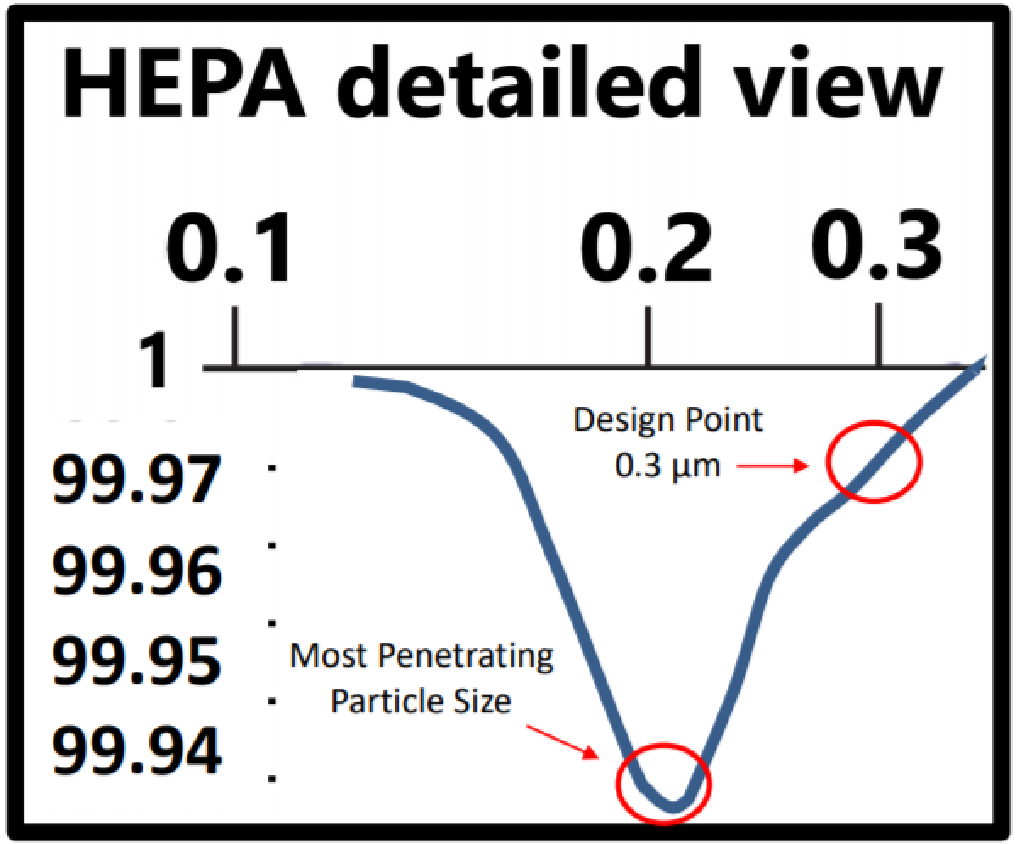
- If filters were not adequately installed, then a portion of the supply air may bypass the filter
- The bypass usually occurs through gaps at the sides and corners of the ducting system
- More particle therefore can enter the room

	Effective MERV with	
Filter original Type	**1-mm gap**	**10- mm gap**
MERV 6	6	<5
MERV 11	11	8
MERV 15	14	8

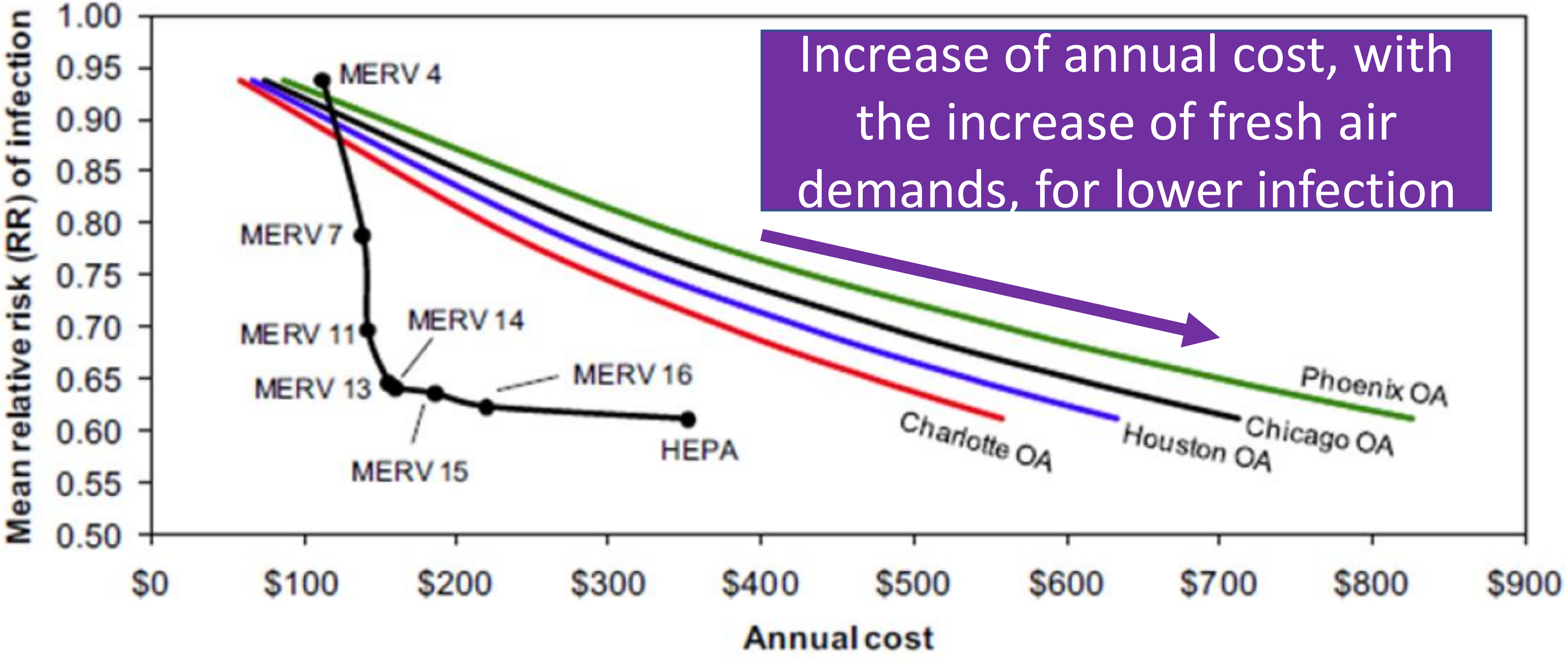
Filter Bypass

Filtration vs. Ventilation

- HEPA may not be the most suitable due to increased cost of:
  1. Filter manufacturing, disposal and replacement
  2. Increase in energy cost due to fan replacements to accommodate higher pressure drops.
- **Selecting MERV 13 filter, along with the recommended ventilation air rates is the most suitable option**



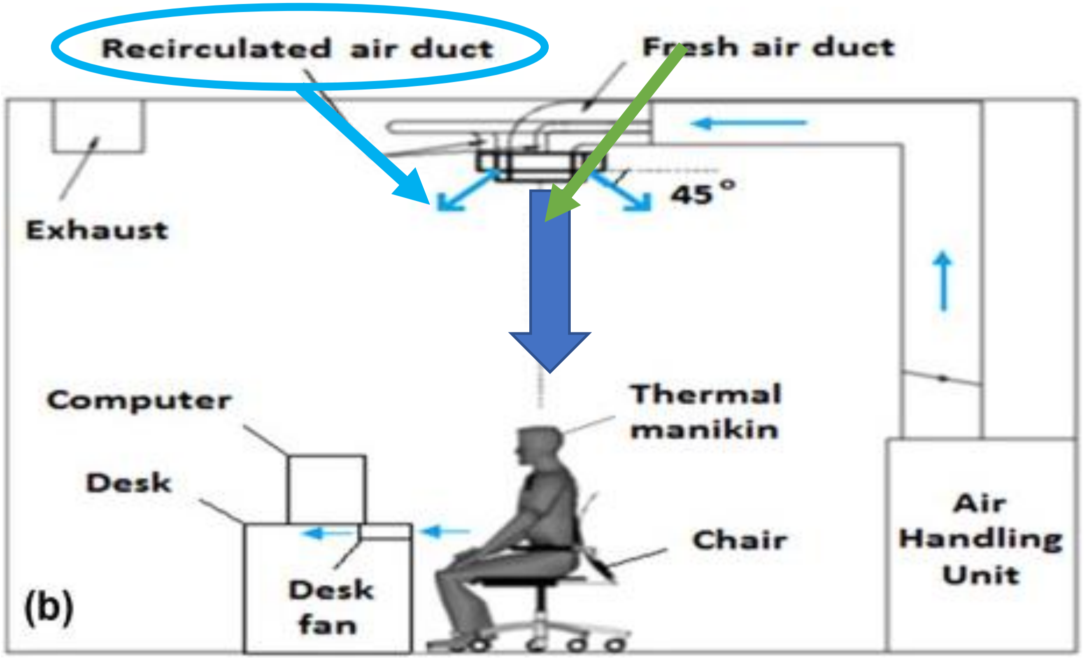
Filtration Vs. Ventilation



Increase of annual cost, with the increase of fresh air demands, for lower infection

Air Distribution

- Air distribution plays a huge role in allowing the pathogens in spreading around an occupied space
- Personalized Ventilation Systems may be preferable in such situations
  1. Fresh Air is directly supplied to the occupant
  2. Recirculated air surrounds the occupant at a 45° angle, creating a canopy, protecting the occupant

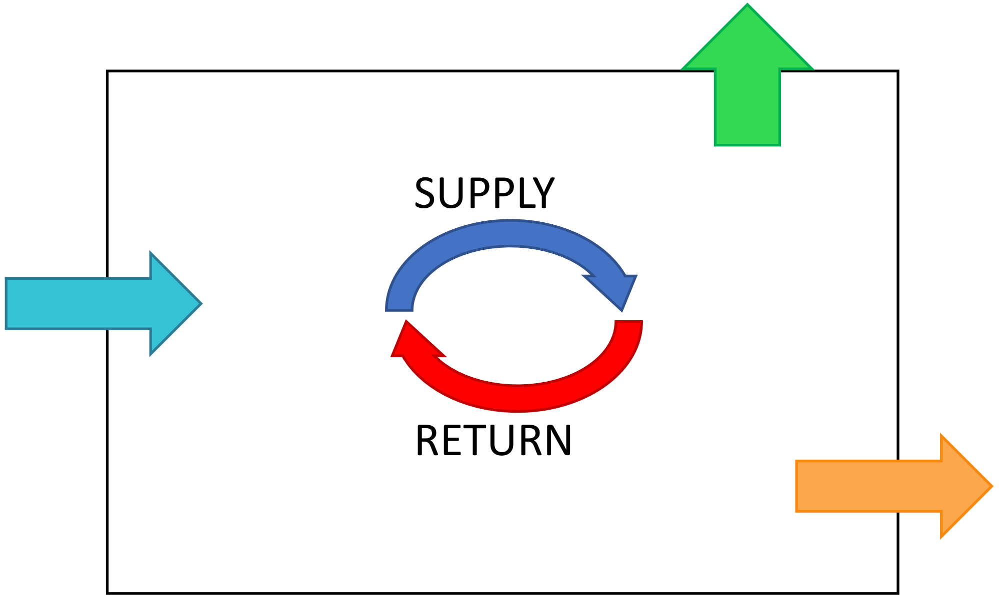


Air Distribution-Pressurization

- Buildings are commonly designed with slightly positive pressure
  - Minimize infiltration
  - Better control of space temperatures
- Pressure Controls
  - Avoid the spread of pathogens from one room to the next

Positive Pressurization

- Space vs. Building
- Building



Typical

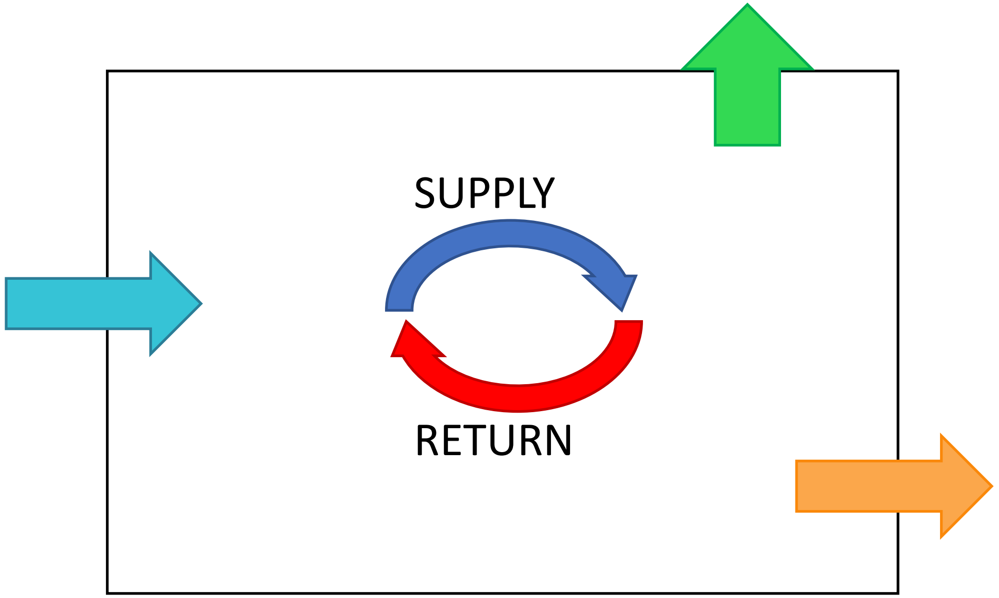
Negative

Neutral

Positive

Negative Pressurization

- Space vs. Building
- Building



Negative

Neutral

Positive

1500 L/s
EXHAUST

SUPPLY

RETURN

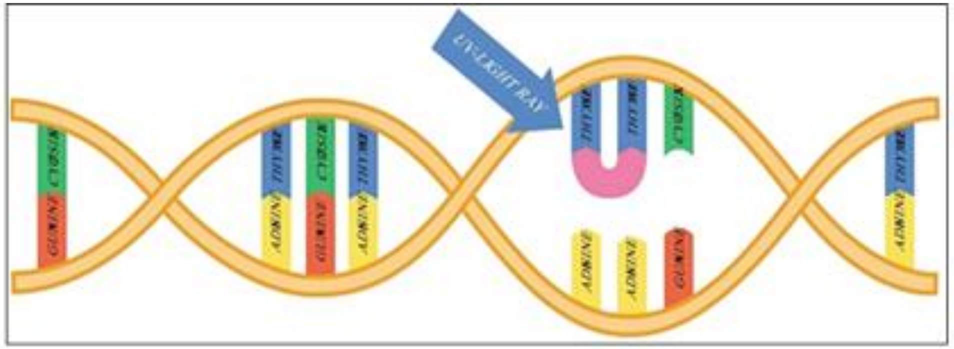
VENTILATION
1000 L/s
+
OUTSIDE AIR
500 L/s

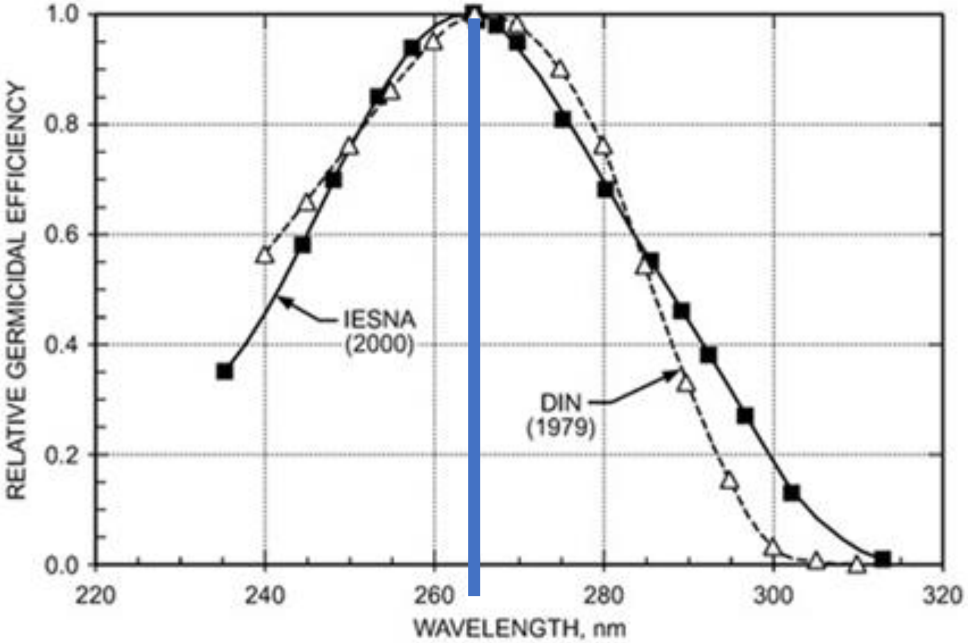
RELIEF
0 L/s

High Exhaust

Disinfection- UV Lighting

- Ultraviolet energy inactivates viral, bacterial, and fungal organisms so they are unable to replicate and potentially cause disease.
- The entire UV spectrum is capable of inactivating microorganisms,
- UV-C energy is the most effective in inactivating germs because its wavelengths are between 100 – 280 nm, known as UVGI-Germicidal Irradiation.
- Optimum wavelength to inactivate germs is around 265 nm.
- Can be installed, provided that safety measures are taken into considerations
- Adding UV lamps should be selected to have features that also eliminate ozone production





265 nm

Types of UV-C Disinfection systems

UV-C In-Duct Air Disinfection

UV-C Upper-Air Disinfection

UV-C In-Duct
Surface Disinfection

UV-C Portable
Room
Decontamination

Temperature and Humidity Controls

- Air temperature and humidity influence infection risk
- Several recent studies recommend 40 –60% RH for infection risk, disease specific, in hot climates
- Decreasing RH can cause

  Lower RH → faster droplet evaporation, less deposition

  Lower RH → dryness of mucus by dry air increases susceptibility

  Lower RH → longer survival/higher infectivity of microorganism

Temperature and Humidity Controls

- Possible concerns of humidification and temperature manipulation:
  1. Different responses occur for different pathogens
  2. Risk of moisture damage/mold growth at higher RH
  3. May reduce effectiveness of UVGI, as the increased humidity can cause pathogens to absorb water and prolong their life
  4. May adversely affect comfort

Humidity Controls

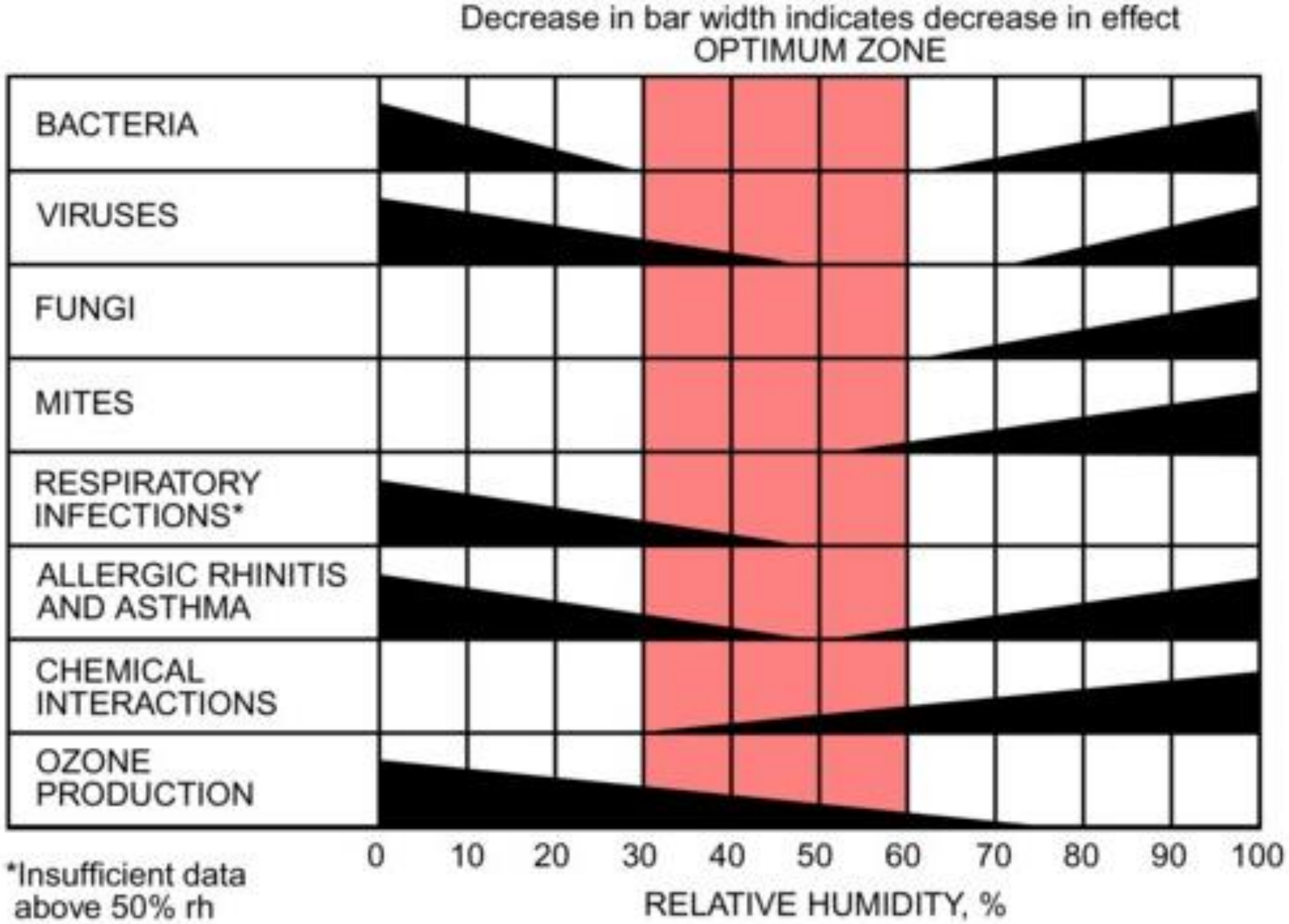
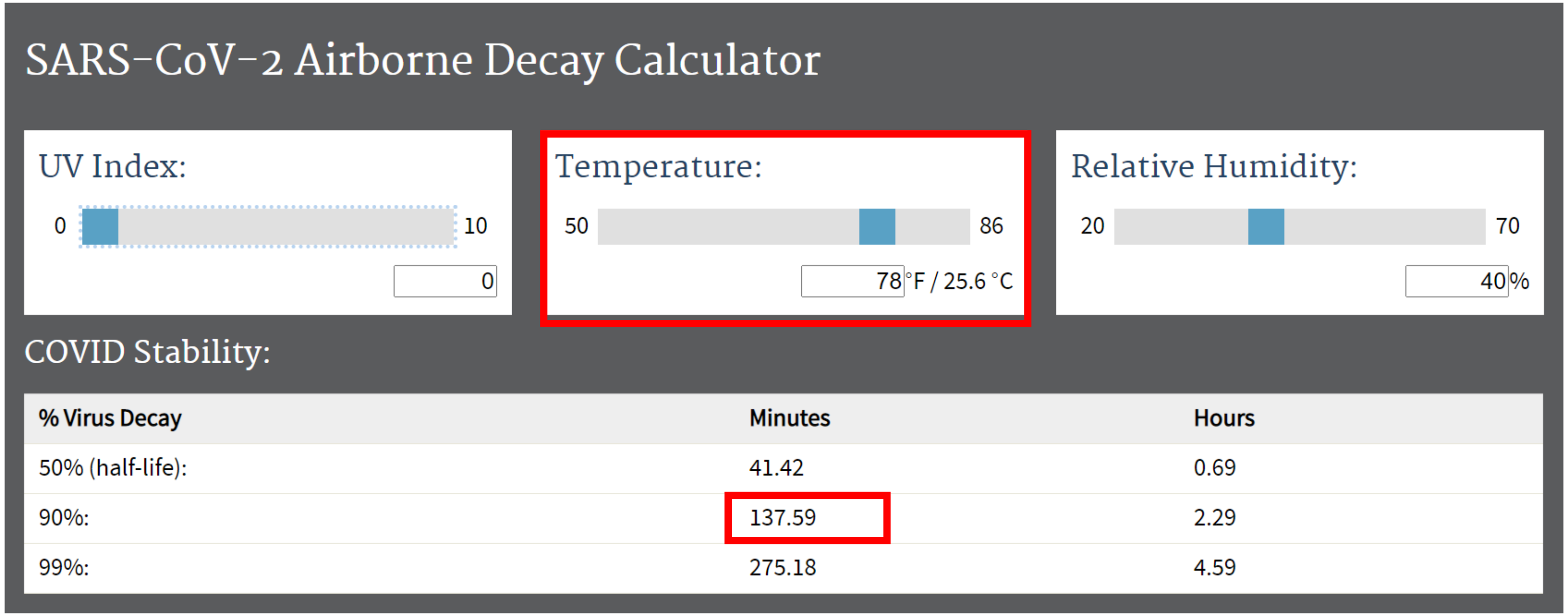


Figure 1. Optimum Humidity Range for Human Comfort and Health

(Adapted from Sterling et al. 1985)

SARS-COV2 AIRBORNE DECAY CALCULATOR



SARS-CoV-2 Airborne Decay Calculator

UV Index: 0

Temperature: 78 °F / 25.6 °C

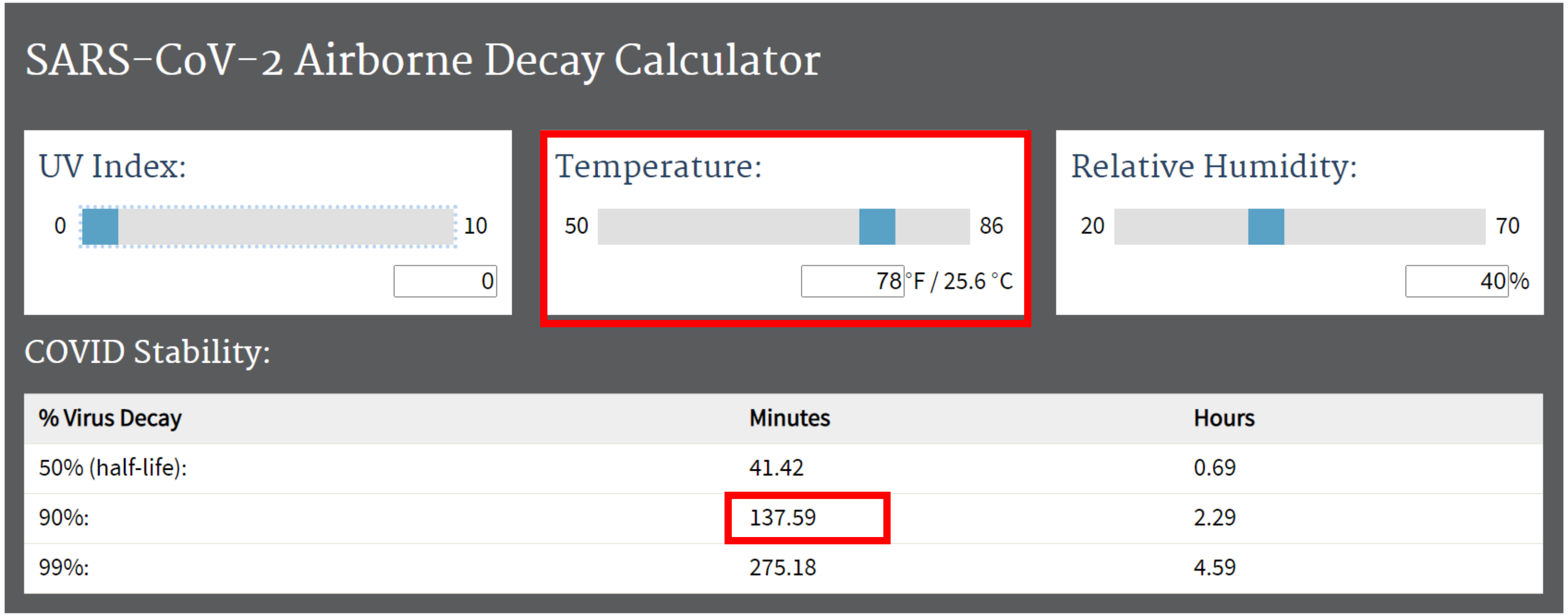
Relative Humidity: 40 %

COVID Stability:

% Virus Decay	Minutes	Hours
50% (half-life):	41.42	0.69
90%:	137.59	2.29
99%:	275.18	4.59

https://www.dhs.gov/science-and-technology/sars-airborne-calculator

SARS-COV2 AIRBORNE DECAY CALCULATOR



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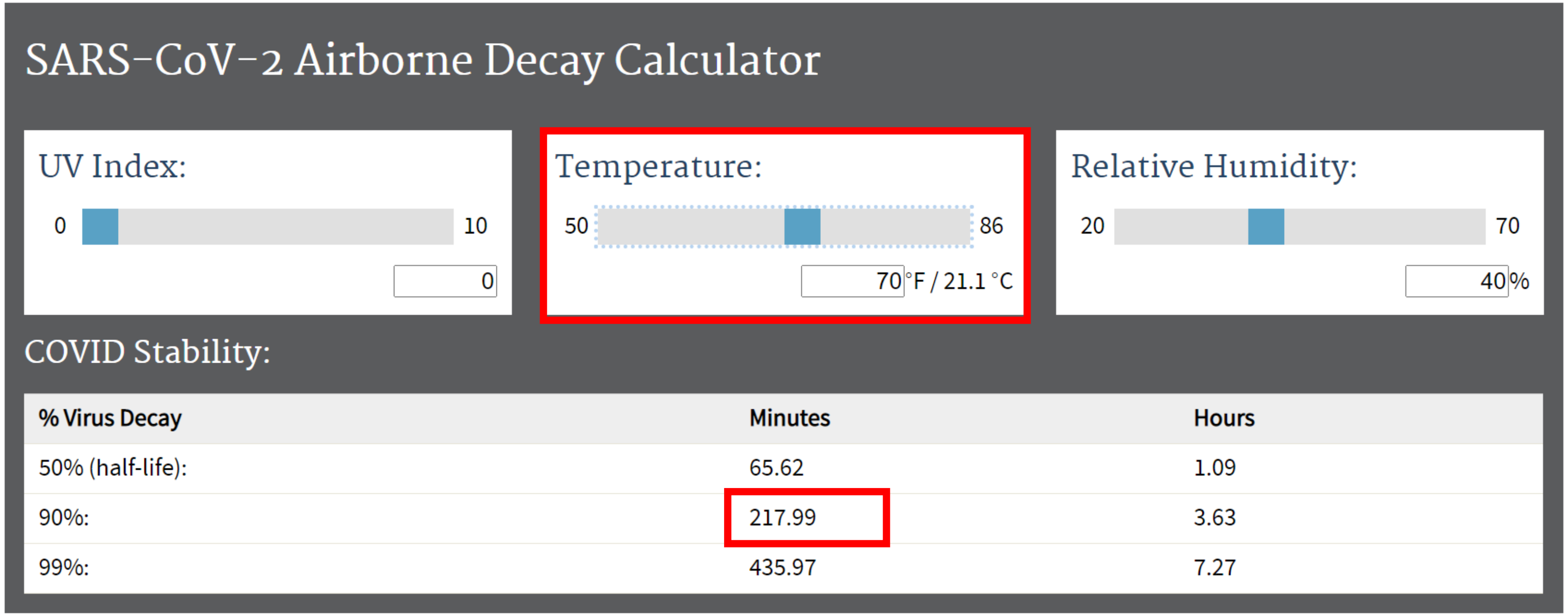


SARS-CoV-2 Airborne Decay Calculator

UV Index: 0

Temperature: 70 °F / 21.1 °C

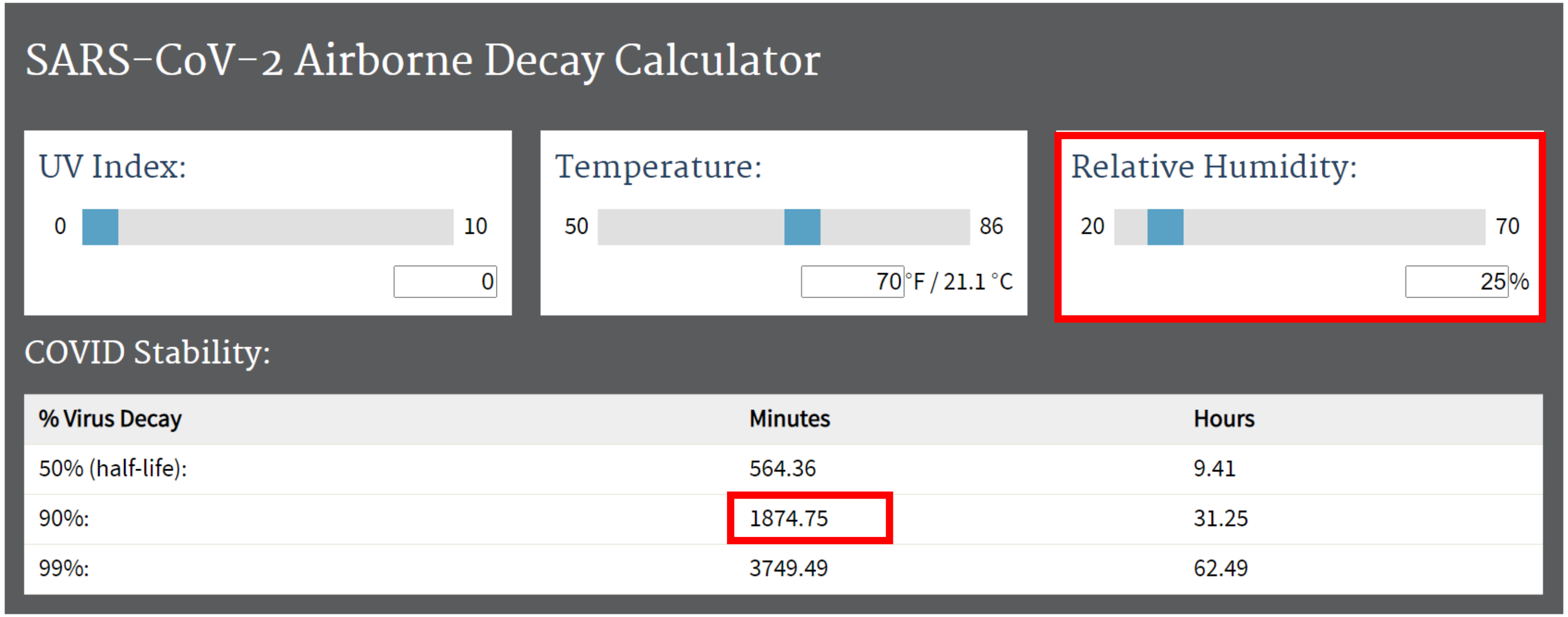
Relative Humidity: 40 %

COVID Stability:

% Virus Decay	Minutes	Hours
50% (half-life):	65.62	1.09
90%:	217.99	3.63
99%:	435.97	7.27

https://www.dhs.gov/science-and-technology/sars-airborne-calculator

SARS-COV2 AIRBORNE DECAY CALCULATOR



SARS-CoV-2 Airborne Decay Calculator

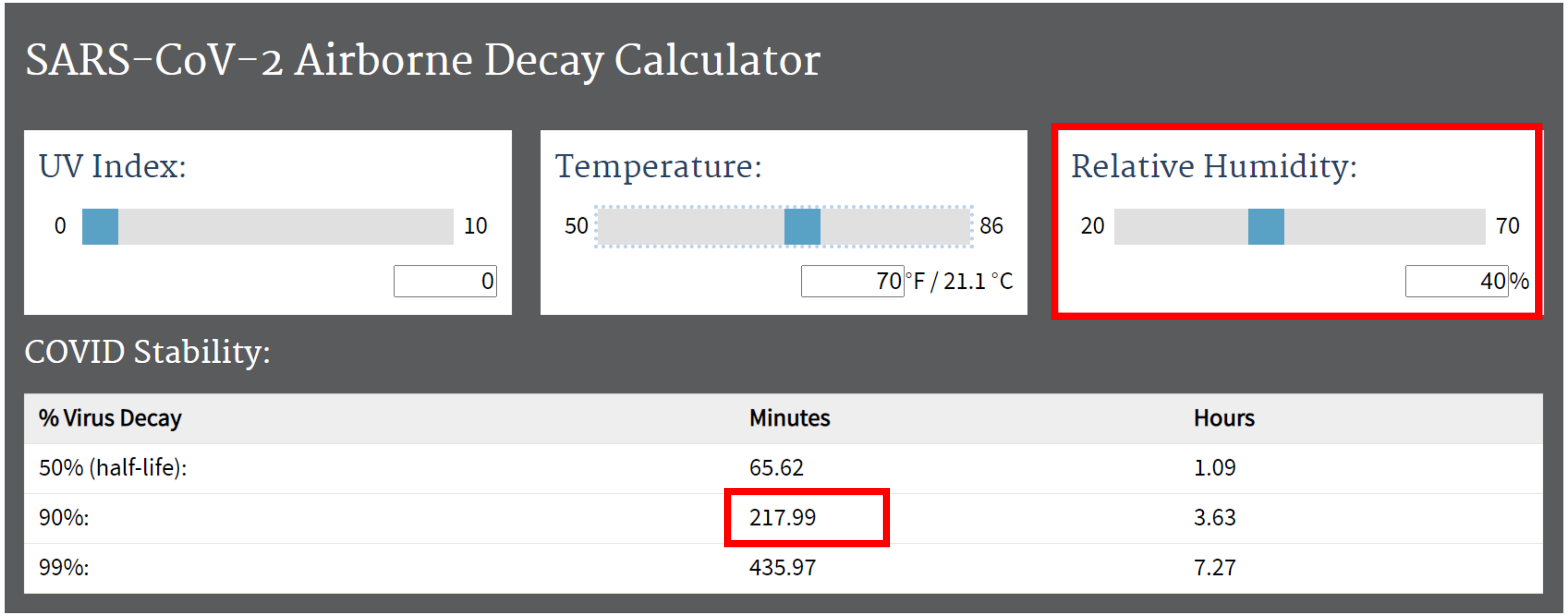
UV Index: 0

Temperature: 70 °F / 21.1 °C

Relative Humidity: 25 %

COVID Stability:

% Virus Decay	Minutes	Hours
50% (half-life):	564.36	9.41
90%:	1874.75	31.25
99%:	3749.49	62.49



SARS-CoV-2 Airborne Decay Calculator

UV Index: 0

Temperature: 70 °F / 21.1 °C

Relative Humidity: 40 %

COVID Stability:

% Virus Decay	Minutes	Hours
50% (half-life):	65.62	1.09
90%:	217.99	3.63
99%:	435.97	7.27

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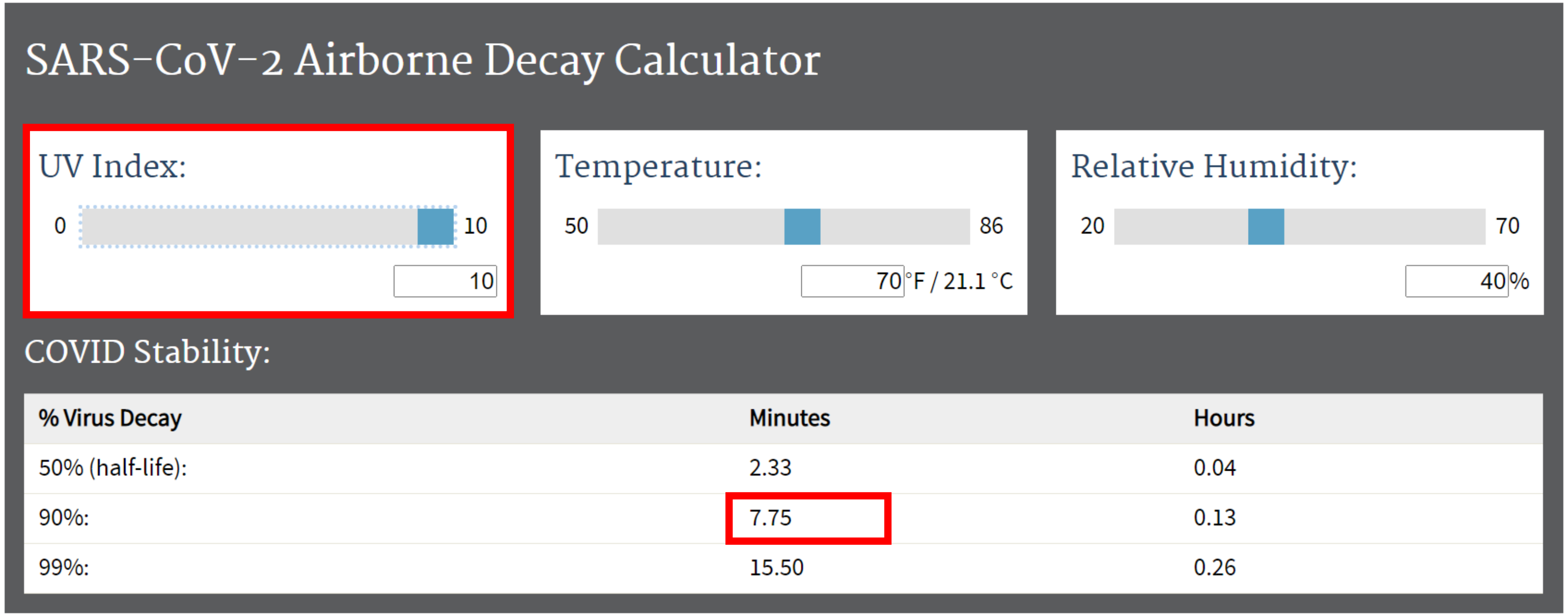
SARS-COV2 AIRBORNE DECAY CALCULATOR



SARS-CoV-2 Airborne Decay Calculator

UV Index:

10

Temperature:

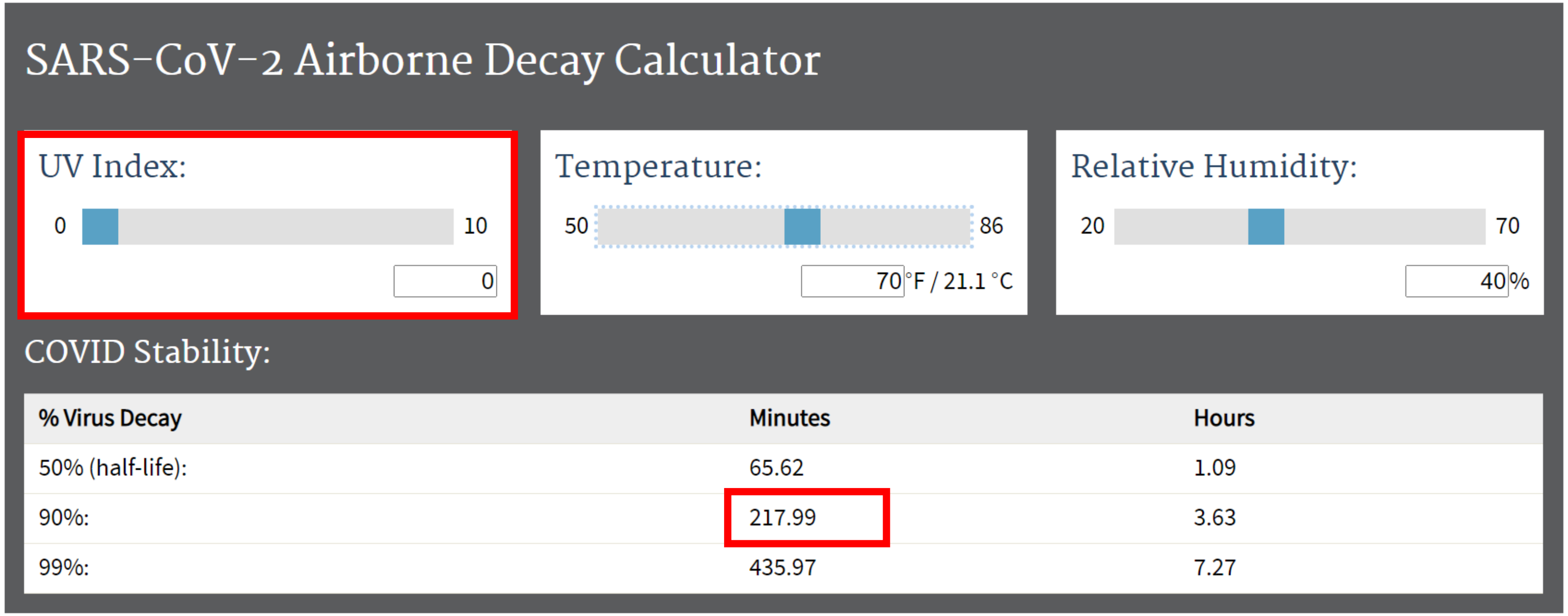
70°F / 21.1 °C

Relative Humidity:

40%

COVID Stability:

% Virus Decay	Minutes	Hours
50% (half-life):	2.33	0.04
90%:	7.75	0.13
99%:	15.50	0.26



SARS-CoV-2 Airborne Decay Calculator

UV Index:

0

Temperature:

70°F / 21.1 °C

Relative Humidity:

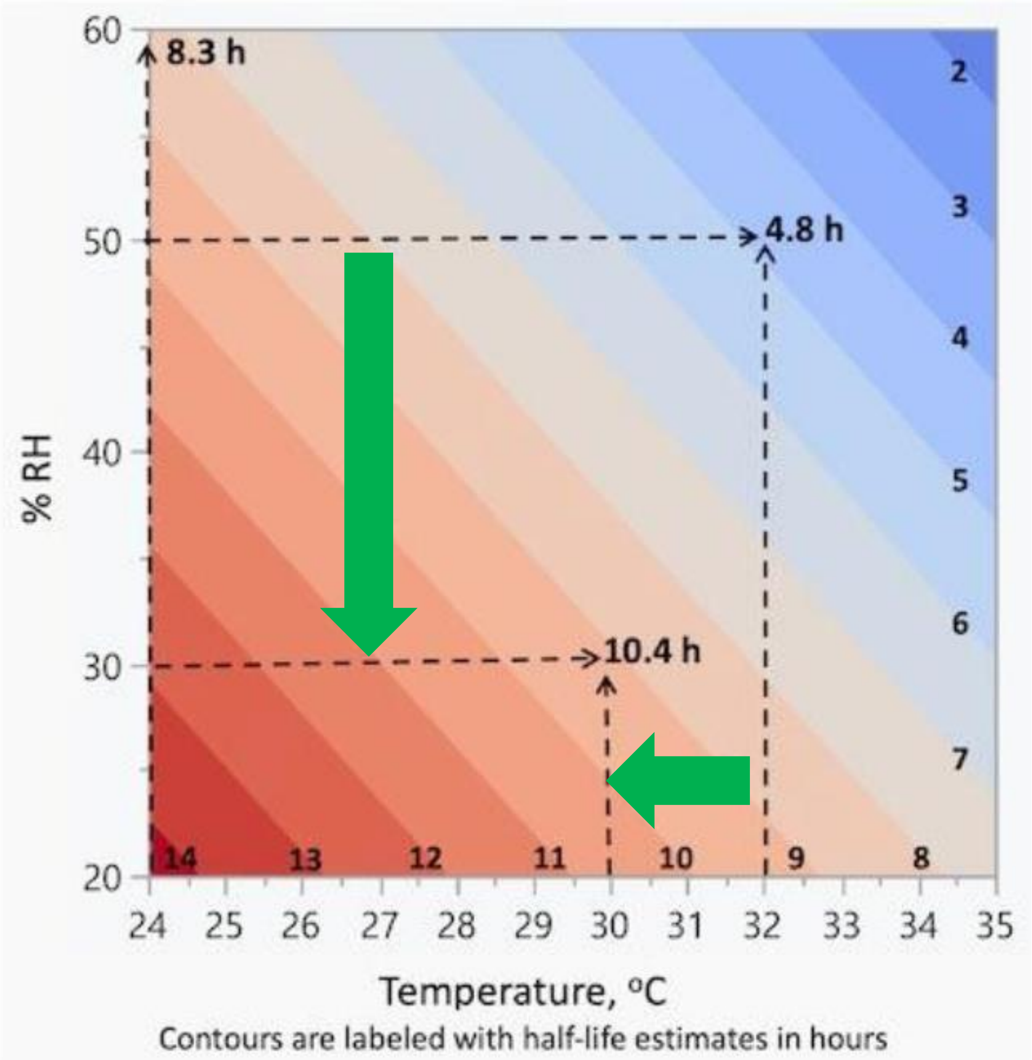
40%

COVID Stability:

% Virus Decay	Minutes	Hours
50% (half-life):	65.62	1.09
90%:	217.99	3.63
99%:	435.97	7.27

https://www.dhs.gov/science-and-technology/sars-airborne-calculator

SARS-COV2 SURFACE DECAY CALCULATOR



Contours are labeled with half-life estimates in hours

https://www.dhs.gov/science-and-technology/sars-calculator

Securing Your Household

- Regardless of the kind of home we live in, better to stay indoors as much as possible to mitigate the spread of the COVID-19 disease.
- If household member is infected, the rest of the members can get infected
- ASHRAE Epidemic Task Force released a set of recommendations for the HVAC at any household

HVAC Recommendation for Homes

- **Maintain normal thermal comfort conditions:**
  - provide acceptable indoor thermal conditions
- **Increase ventilation rate:**
  - The home's ventilation system should always be operated at least to provide the flow rate intended (ASHRAE Standard 62.2).
  - If mechanical ventilation systems are not available in single-family homes, opening multiple windows is an acceptable alternative, provided the open windows do not cause excessive draft

HVAC Recommendation for Homes

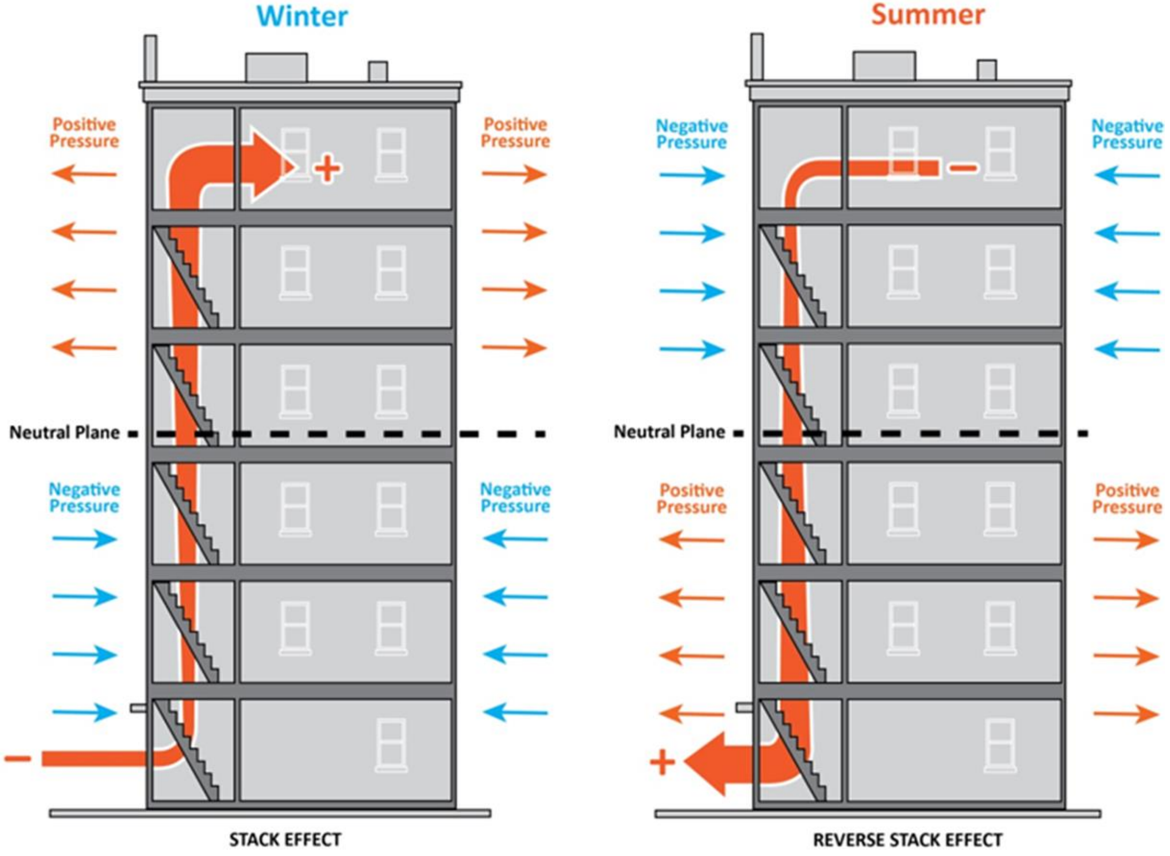
- **Operate Restroom Exhaust Fans:**
  - ➢Exhaust fans in bathrooms, toilets and lavatories should be operated whenever the facilities are in use. If possible, they should be operated continuously.
  - ➢Toilet lids should be closed as much as possible.
- **Operate Stand-Alone Air Cleaners:**
  - ➢Stand-alone air cleaners (often called air purifiers) with particle filters should be operated continuously, if available.
  - ➢If there is only one, it should be placed in the area where most people in the household spend their time.

HVAC Recommendation for Homes

- **Increase Room Air Motion:**
    - ➢Increased air motion within a room, such as from a ceiling fan, may be used to augment, ventilation effectiveness and improve thermal comfort conditions
- **Install High Efficiency Media Filters:**
    - ➢Filters on AC units should be upgraded to high-efficiency filters (such as MERV 14) or higher, when the system allows it.
    - ➢Always wear PPE when replacing the filters
- **Operate Ultra-Violet (UV) Germicidal Irradiation:**
    - ➢UVGI systems should be maximally operated according to manufacturer instructions

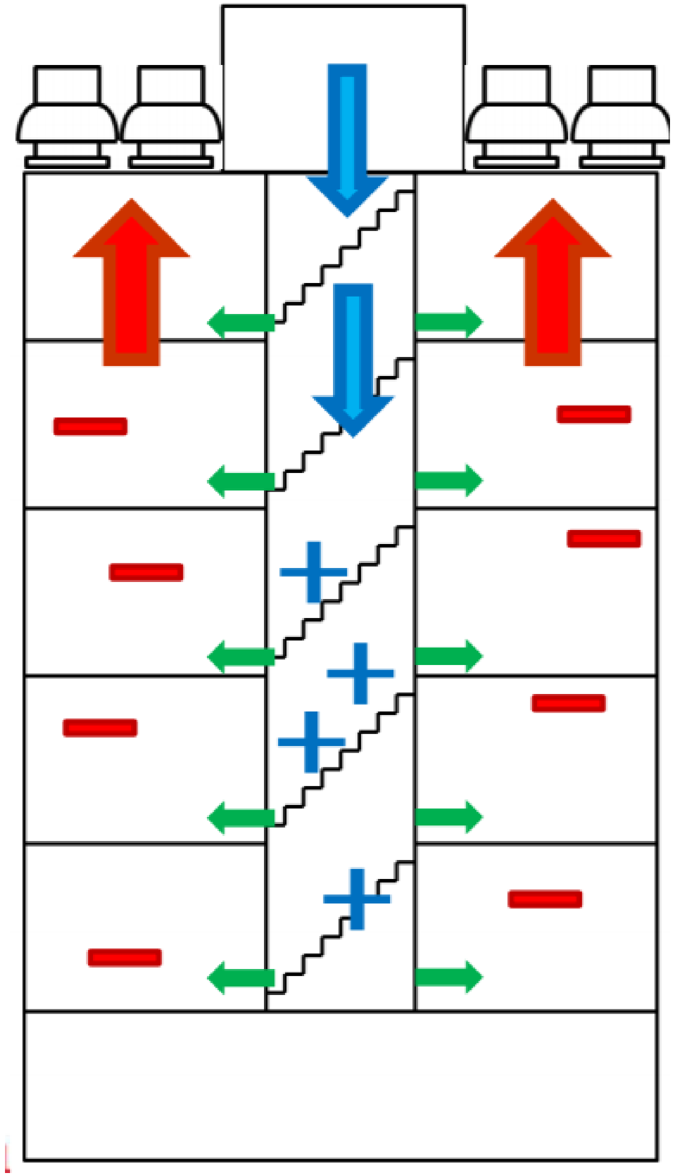
In Multi-family Dwelling Units (e.g. Apartments)

- Stack effect: is the movement of air into and out of buildings from air buoyancy.
- In the winter: warmer air rises through the floors of the building, forces cold air to enter from the bottom floors
- In the summer: the reverse process occurs, cooler air in the building precipitates, dropping to the bottom floors, cause suction of hot air from the top floors



In Multi-family Dwelling Units (e.g. Apartments)

- **Pressurization in the Lobby to reduce the stack effect especially during colder season.**
  - ➢Exhaust systems is recommended to keep the home below the pressure in the corridor or hallway.
  - ➢This ensures that contaminant from one apartment would never enter another
  - ➢Open windows should be minimized to meet minimum ventilation requirements
  - ➢Placement of seals on windows and exterior door to reduce infiltrations (interior door to corridor needs to have air movement)



Creating Isolation Spaces at Homes

- Let’s take this following hypothetical situation:
  1. Your family member tested positive for SARS-CoV-2
  2. He or she is showing mild symptoms
  3. Nothing serious, no need for hospitalization, or no space in hospitals

- So how can you create an isolation system at home, to protect the rest of the family?

Creating Isolation Spaces at Homes

- **Select Isolation Space :**
  - ✓Space should be on a low floor during the cooling season.
  - ✓The isolation space should have its own restroom facilities with exhaust fan running continuously.
  - ✓The return system of the isolation space should not be common with other spaces (seal return grill).
  - ✓Separate HVAC system is recommended for the isolation zone.
  - ✓Even if there is a closable door, plastic sheets should be hung between the isolation space and the common space.
  - ✓Exhaust ventilation should be provided. (can easily added on the window)
  - ✓Exhaust fans in the main part of the home should be operated only on an as needed basis
  - ✓Operate Stand-Alone Air Cleaner
  - ✓Consider HEPA filter cleaner on exhaust if the outlet to exterior is accessible to pedestrians.