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?

- Effect on People:
  - Nausea and Headaches
  - Respiratory Issues
  - Fatigue

Still Indoor Air + Excessive humidity = Molds and Odors
What are the Symptoms of low IAQ?

• Increase in other contaminants including:
  • Carbon Monoxide (CO).
  • Oxides of Nitrogen (NO\textsubscript{x}).
  • Oxides of Sulfur (SO\textsubscript{x}).
  • Carbon Dioxide (CO\textsubscript{2}).
  • Particulate Matter (PM2.5, PM 10)
  • Volatile organic compounds (E.g. Formaldehyde HCHC)
Short-term Health 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.
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?

- Poor filtration systems
- Indoor overcrowding
- Low building ventilation
- Improper ducting installations
- 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

- Heat Generated
- Skin
- Surface in Environment
- Radiation
- Convection
- Sensible Heat
- Sweat
- Exposed Surface
- Clothing
- Respiration
- Evaporative Heat Loss
- Body

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
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

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

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

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

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 the virus.

Lednicky et al (2020) https://doi.org/10.1101/2020.08.03.20167395
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 μm 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 μm) to 41 hours (0.5 μm), 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

<table>
<thead>
<tr>
<th>Particulate Contaminants</th>
<th>Size Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Hair</td>
<td>(70 - 100 microns)</td>
</tr>
<tr>
<td>Human Sneeze</td>
<td>(10 - 100 microns)</td>
</tr>
<tr>
<td>Pet Dander</td>
<td>(0.5 - 100 microns)</td>
</tr>
<tr>
<td>Pollen</td>
<td>(5 - 100 microns)</td>
</tr>
<tr>
<td>Spores from Plants</td>
<td>(6 - 100 microns)</td>
</tr>
<tr>
<td>Mold</td>
<td>(2 - 20 microns)</td>
</tr>
<tr>
<td>Smoke</td>
<td>(.01 - 1 micron)</td>
</tr>
<tr>
<td>Dust Mite Dropping</td>
<td>(0.5 – 1.5 microns)</td>
</tr>
<tr>
<td>Household Dust</td>
<td>(.05 - 100 microns)</td>
</tr>
<tr>
<td>Skin Flakes</td>
<td>(0.4 - 10 microns)</td>
</tr>
<tr>
<td>Bacteria</td>
<td>(0.35 - 10 microns)</td>
</tr>
<tr>
<td>Viruses</td>
<td>(0.1 microns)</td>
</tr>
</tbody>
</table>
Gaseous Contaminants

• Usually are combustion products such as:
  • Carbon Monoxide (CO).
  • Oxides of Nitrogen (NO\textsubscript{x}).
  • Oxides of Sulfur (SO\textsubscript{x}).
  • Carbon Dioxide (CO\textsubscript{2}).
  • Tobacco Smoke Components

• Irritant low concentration and can cause severe health effects in high concentration.
Levels of Gaseous Contaminants

- Carbon Dioxide $\text{CO}_2$ (350-1000 ppm)
- Carbon Monoxide CO (must not exceed 9 ppm)
- Nitrogen Dioxide $\text{NO}_2$ (must not exceed 0.05 ppm)
- Ozone $\text{O}_3$ (must not exceed 0.07 ppm)
- Sulphur dioxide $\text{SO}_2$ (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?

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

<table>
<thead>
<tr>
<th>% Ventilation Air</th>
<th>Coil Pressure Drop (ft H₂O)</th>
<th>Total Capacity (Tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>5.04</td>
<td>37</td>
</tr>
<tr>
<td>40</td>
<td>7.90</td>
<td>48.5</td>
</tr>
<tr>
<td>50</td>
<td>9.49</td>
<td>54.2</td>
</tr>
<tr>
<td>70</td>
<td>13.43</td>
<td>65.9</td>
</tr>
<tr>
<td>90</td>
<td>18.48</td>
<td>77.4</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>OA%</th>
<th>Load Increase %</th>
<th>Sensible Capacity of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>20%</td>
<td>N/A</td>
<td>74%</td>
</tr>
<tr>
<td>50%</td>
<td>45%</td>
<td>57%</td>
</tr>
<tr>
<td>80%</td>
<td>90%</td>
<td>48%</td>
</tr>
</tbody>
</table>
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
Commercial Buildings Ventilation

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

\[ V = R_p P_z + R_a A_z \]

- \( R_p \) = 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.)

<table>
<thead>
<tr>
<th>Occupancy Category</th>
<th>People Outdoor Air Rate $R_p$</th>
<th>Area Outdoor Air Rate $R_a$</th>
<th>Default Values</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cfm/person L/s-person</td>
<td>cfm/ft$^2$ L/s$^2$m$^2$</td>
<td>Occupant Density (see Note 4)</td>
<td>Combined Outdoor Air Rate (see Note 5)</td>
</tr>
<tr>
<td>Educational Facilities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daycare (through age 4)</td>
<td>10</td>
<td>5</td>
<td>0.18</td>
<td>0.9</td>
</tr>
<tr>
<td>Daycare sickroom</td>
<td>10</td>
<td>5</td>
<td>0.18</td>
<td>0.9</td>
</tr>
<tr>
<td>Classrooms (ages 5–8)</td>
<td>10</td>
<td>5</td>
<td>0.12</td>
<td>0.6</td>
</tr>
<tr>
<td>Classrooms (age 9 plus)</td>
<td>10</td>
<td>5</td>
<td>0.12</td>
<td>0.6</td>
</tr>
<tr>
<td>Lecture classroom</td>
<td>7.5</td>
<td>3.8</td>
<td>0.06</td>
<td>0.3</td>
</tr>
<tr>
<td>Lecture hall (fixed seats)</td>
<td>7.5</td>
<td>3.8</td>
<td>0.06</td>
<td>0.3</td>
</tr>
<tr>
<td>Art classroom</td>
<td>10</td>
<td>5</td>
<td>0.18</td>
<td>0.9</td>
</tr>
<tr>
<td>Science laboratories</td>
<td>10</td>
<td>5</td>
<td>0.18</td>
<td>0.9</td>
</tr>
<tr>
<td>University/college laboratories</td>
<td>10</td>
<td>5</td>
<td>0.18</td>
<td>0.9</td>
</tr>
<tr>
<td>Wood/metal shop</td>
<td>10</td>
<td>5</td>
<td>0.18</td>
<td>0.9</td>
</tr>
<tr>
<td>Computer lab</td>
<td>10</td>
<td>5</td>
<td>0.12</td>
<td>0.6</td>
</tr>
<tr>
<td>Media center</td>
<td>10</td>
<td>5</td>
<td>0.12</td>
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</tr>
<tr>
<td>Music/theater/dance</td>
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<td>5</td>
<td>0.06</td>
<td>0.3</td>
</tr>
<tr>
<td>Multi-use assembly</td>
<td>7.5</td>
<td>3.8</td>
<td>0.06</td>
<td>0.3</td>
</tr>
<tr>
<td>Office space</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
</tr>
<tr>
<td>Reception areas</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
</tr>
<tr>
<td>Telephone/data entry</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
</tr>
<tr>
<td>Main entry lobbies</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
</tr>
</tbody>
</table>
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>
<thead>
<tr>
<th>Occupancy Category</th>
<th>People Outdoor Air Rate $R_{p}$</th>
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<th>Combined Outdoor Air Rate</th>
<th>Air Class</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>cfm/person</td>
<td>L/s/person</td>
<td>cfm/ft²</td>
<td>L/s·m²</td>
<td>#/1000 ft² or #/100 m²</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>0.6</td>
<td>25</td>
<td>15</td>
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<td>0.3</td>
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<td>8</td>
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<td>17</td>
</tr>
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<td>Reception areas</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
<td>30</td>
<td>7</td>
</tr>
<tr>
<td>Telephone/data entry</td>
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<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
<td>60</td>
<td>6</td>
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<tr>
<td>Main entry lobbies</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
<td>0.3</td>
<td>10</td>
<td>11</td>
</tr>
</tbody>
</table>

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.)
Ventilation Rate Example (Commercial)

\[ V = R_p P_z + R_a A_z \]

\[ V = (7.5)(208)+(0.06)(1,822) \]

\[ V = 1670 \text{ CFM}_{OA} \]

\[ R_p = 7.5 \text{ CFM/person} \]

\[ P_z = 208 \text{ people} \]

\[ R_a = 0.06 \text{ CFM/ft}^2 \]

\[ A_z = 1,822 \text{ ft}^2 \]
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
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) $Q = 0.01A_{floor} + 7.5(N_{br} + 1)$ for I-P units or,
     b) $Q = 0.05A_{floor} + 3.5(N_{br} + 1)$ for SI units
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.

\[ ACH = CFM \times \frac{60}{Area \times Height} \]
**Ventilation Rates in Healthcare Facilities**

**Table 7.1 Design Parameters (Continued)**

<table>
<thead>
<tr>
<th>Function of Space</th>
<th>Pressure Relationship to Adjacent Areas (in)</th>
<th>Minimum Outdoor ach</th>
<th>Minimum Total ach</th>
<th>All Room Air Exhausted Directly to Outdoors (if)</th>
<th>Air Recirculated by Means of Room Units (if)</th>
<th>Design Relative Humidity (if), %</th>
<th>Design Temperature (if), °F/°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear medicine hot lab</td>
<td>Negative</td>
<td>NR</td>
<td>6</td>
<td>Yes</td>
<td>No</td>
<td>NR</td>
<td>70–75/21–24</td>
</tr>
<tr>
<td>Nuclear medicine treatment room</td>
<td>Negative</td>
<td>2</td>
<td>6</td>
<td>Yes</td>
<td>NR</td>
<td>NR</td>
<td>70–75/21–24</td>
</tr>
</tbody>
</table>

**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 | 72–76/22–26 |
| Clean workroom | Positive | 2 | 4 | NR | No | max 60 | 72–76/22–26 |
| Sterile storage | Positive | 2 | 4 | NR | No | max 60 | 72–76/22–26 |

**Service**

| Food preparation center (if) | NR | 2 | 10 | NR | No | NR | 72–76/22–26 |
| Warewashing | Negative | NR | 10 | Yes | No | NR | NR |
| Dietary storage | NR | NR | 2 | NR | No | NR | 72–76/22–26 |
| 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 | No | NR | 72–76/22–26 |
| 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 | 72–76/22–26 |
| 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.

\[
\text{ACH} = \frac{CFM \times 60}{(\text{Area} \times \text{Height})}
\]

So \[ CFM = ACH \times \frac{(\text{Area} \times \text{Height})}{60} \]

\[ CFM = 4 \times \frac{20 \times 15 \times 10}{60} = 200 \text{ CFM} \]
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

Infiltration

- Window Crack
- Outside Air
- Closed Window

Natural Ventilation

- Outside Air
- Window
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

Supply Air

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

<table>
<thead>
<tr>
<th>MERV 5-8 filters</th>
<th>Removes</th>
<th>Coarse particles</th>
</tr>
</thead>
<tbody>
<tr>
<td>MERV 13-16 filters</td>
<td>Removes fine and coarse particles at higher efficiencies</td>
<td></td>
</tr>
</tbody>
</table>
# MERV Rates

<table>
<thead>
<tr>
<th>Standard 52.2 Minimum Efficiency Reporting Value (MERV)</th>
<th>Composite Average Particle Size Efficiency, % in Size Range, μm</th>
<th>Average Arrestance, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range 1 0.30 to 1.0</td>
<td>Range 2 1.0 to 3.0</td>
<td>Average Arrestance, %</td>
</tr>
<tr>
<td>1</td>
<td>N/A</td>
<td>$E_1 \leq 20$</td>
</tr>
<tr>
<td>2</td>
<td>N/A</td>
<td>$E_1 \leq 20$</td>
</tr>
<tr>
<td>3</td>
<td>N/A</td>
<td>$E_1 \leq 20$</td>
</tr>
<tr>
<td>4</td>
<td>N/A</td>
<td>$E_1 \leq 20$</td>
</tr>
<tr>
<td>5</td>
<td>N/A</td>
<td>$20 \leq E_3$</td>
</tr>
<tr>
<td>6</td>
<td>N/A</td>
<td>$35 \leq E_3$</td>
</tr>
<tr>
<td>7</td>
<td>N/A</td>
<td>$50 \leq E_3$</td>
</tr>
<tr>
<td>8</td>
<td>N/A</td>
<td>$20 \leq E_2$</td>
</tr>
<tr>
<td>9</td>
<td>N/A</td>
<td>$35 \leq E_2$</td>
</tr>
<tr>
<td>10</td>
<td>N/A</td>
<td>$50 \leq E_2$</td>
</tr>
<tr>
<td>11</td>
<td>$20 \leq E_1$</td>
<td>$65 \leq E_2$</td>
</tr>
<tr>
<td>12</td>
<td>$35 \leq E_1$</td>
<td>$80 \leq E_2$</td>
</tr>
<tr>
<td>13</td>
<td>$50 \leq E_1$</td>
<td>$85 \leq E_2$</td>
</tr>
<tr>
<td>14</td>
<td>$75 \leq E_1$</td>
<td>$90 \leq E_2$</td>
</tr>
<tr>
<td>15</td>
<td>$85 \leq E_1$</td>
<td>$90 \leq E_2$</td>
</tr>
<tr>
<td>16</td>
<td>$95 \leq E_1$</td>
<td>$95 \leq E_2$</td>
</tr>
</tbody>
</table>

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
Typical Filter Application

Consider need for filtration of exhaust air.
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

<table>
<thead>
<tr>
<th>Filter original Type</th>
<th>Effective MERV with 1-mm gap</th>
<th>Effective MERV with 10-mm gap</th>
</tr>
</thead>
<tbody>
<tr>
<td>MERV 6</td>
<td>6</td>
<td>&lt;5</td>
</tr>
<tr>
<td>MERV 11</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>MERV 15</td>
<td>14</td>
<td>8</td>
</tr>
</tbody>
</table>
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**

- VENTILATION 1000 L/s
- SUPPLY
- RETURN
- 250 L/s EXHAUST
- RELIEF 750 L/s

**Neutral**

- 750 L/s

**Positive**

- 1000 L/s
Negative Pressurization

• Space vs. Building
• Building

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

1500 L/s EXHAUST

SUPPLY

RETURN

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
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-CoV-2 Airborne Decay Calculator**

### COVID Stability:

<table>
<thead>
<tr>
<th>% Virus Decay</th>
<th>Minutes</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>50% (half-life):</td>
<td>41.42</td>
<td>0.69</td>
</tr>
<tr>
<td>90%:</td>
<td>137.59</td>
<td>2.29</td>
</tr>
<tr>
<td>99%:</td>
<td>275.18</td>
<td>4.59</td>
</tr>
</tbody>
</table>

### COVID Stability (Different Conditions):

<table>
<thead>
<tr>
<th>% Virus Decay</th>
<th>Minutes</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>50% (half-life):</td>
<td>65.62</td>
<td>1.09</td>
</tr>
<tr>
<td>90%:</td>
<td>217.99</td>
<td>3.63</td>
</tr>
<tr>
<td>99%:</td>
<td>435.97</td>
<td>7.27</td>
</tr>
</tbody>
</table>

SARS-COV2 AIRBORNE DECAY CALCULATOR

SARS-CoV-2 Airborne Decay Calculator

UV Index: | Temperature: | Relative Humidity:
---|---|---
0 | 50 | 20

COVID Stability:

<table>
<thead>
<tr>
<th>% Virus Decay</th>
<th>Minutes</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>50% (half-life):</td>
<td>564.36</td>
<td>9.41</td>
</tr>
<tr>
<td>90%:</td>
<td>1874.75</td>
<td>31.25</td>
</tr>
<tr>
<td>99%:</td>
<td>3749.49</td>
<td>62.49</td>
</tr>
</tbody>
</table>

SARS-CoV-2 Airborne Decay Calculator

UV Index: | Temperature: | Relative Humidity:
---|---|---
0 | 50 | 20

COVID Stability:

<table>
<thead>
<tr>
<th>% Virus Decay</th>
<th>Minutes</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>50% (half-life):</td>
<td>65.62</td>
<td>1.09</td>
</tr>
<tr>
<td>90%:</td>
<td>217.99</td>
<td>3.63</td>
</tr>
<tr>
<td>99%:</td>
<td>435.97</td>
<td>7.27</td>
</tr>
</tbody>
</table>

### SARS-CoV-2 Airborne Decay Calculator

#### UV Index: 0

<table>
<thead>
<tr>
<th>% Virus Decay</th>
<th>Minutes</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>50% (half-life):</td>
<td>2.33</td>
<td>0.04</td>
</tr>
<tr>
<td>90%:</td>
<td><strong>7.75</strong></td>
<td>0.13</td>
</tr>
<tr>
<td>99%:</td>
<td>15.50</td>
<td>0.26</td>
</tr>
</tbody>
</table>

#### Temperature: 86°F / 21.1°C

<table>
<thead>
<tr>
<th>% Virus Decay</th>
<th>Minutes</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>50% (half-life):</td>
<td>65.62</td>
<td>1.09</td>
</tr>
<tr>
<td>90%:</td>
<td><strong>217.99</strong></td>
<td>3.63</td>
</tr>
<tr>
<td>99%:</td>
<td>435.97</td>
<td>7.27</td>
</tr>
</tbody>
</table>

#### Relative Humidity: 70%

SARS-COV2 SURFACE DECAY 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.