How Infectious Diseases Transmit

Routes of Transmission

- Droplets
  - Direct contact
  - Indirect contact
- Contact
  - Small airborne particles (an aerosol)
How Infectious Diseases Transmit

Illustration of the aerobiology of droplets and aerosols produced by an infected patient:

- The patient generates droplets by coughing or sneezing
- Droplets evaporated to become droplet nuclei
- Droplets fall due to gravity
- Droplets land on a surface and become desiccated. It can be ejected back into the air by bed-making activities.
How Infectious Diseases Transmit

U.S. health officials say Americans shouldn’t wear face masks to prevent coronavirus — here are 3 other reasons not to wear them

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How Infectious Diseases Transmit

Why we care about viruses transmitting through aerosols?

- Air ventilation won’t have a significant impact on the concentration, velocity, and direction of the respiratory droplets with bigger sizes [1]

- Aerosols travel a relatively long distance and can be significantly impacted by the building heating, ventilating, and air-conditioning (HVAC) system [2]


Mathematical Model of Airborne Infection

\[ C = S \left(1 - e^{-Iqpt/Q}\right) \]

- \( C \) = number of new infections;
- \( I \) = number of infectors;
- \( S \) = number of susceptibles;
- \( q \) = number of doses of airborne infection added to the air;
- \( p \) = pulmonary ventilation per susceptible; typically 0.6 m\(^3\)/h;
- \( t \) = exposure time, typically 8 hours;
- \( Q \) = volume flow rate of fresh or disinfected air (m\(^3\)/h)

Tuberculosis: 1.25~249 qph
Measles: 5,480 qph
## Characteristics of Transmission Through Aerosols

<table>
<thead>
<tr>
<th>Transmission Types</th>
<th>Characteristics</th>
<th>Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obligate</td>
<td>Only transmit through aerosols, aerodynamic diameters of the particles between 1~ 5 ( \mu m )</td>
<td>Mycobacterium tuberculosis</td>
</tr>
<tr>
<td>Preferential</td>
<td>Transmit through multiple routes, predominantly by aerosols</td>
<td>Measles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chicken pox</td>
</tr>
<tr>
<td>Opportunistic</td>
<td>Transmit through multiple routes, can by aerosols when in favorable conditions</td>
<td>To be determined</td>
</tr>
</tbody>
</table>

My Research on Mycobacterium Tuberculosis Transmission
Flu virus can transmit through aerosols, but it is not the main route

Common flu virus and rhinovirus (common cold), can transmit through aerosols
Cases that viruses transmit through aerosols

- In an Alaska Airline airplane, 72% of the 54 passengers were infected with flu, due to the airplane’s recirculated air ventilation system.[1]

- In the 1986 H1N1 period, researchers arranged the susceptibles to be over 6.5 feet (2 meters) from the infected patient; the susceptibles were still infected.[2]

- A SARS Coronavirus outbreak in a high-rise building in Hong Kong (Amoy Gardens) was due to the exhaust fans in restrooms [3]

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1. Increase outdoor air
2. Control airflow direction
3. Control room air differential pressure
4. Personalized ventilation
5. Use high-efficiency filter
6. Utilize UVGI

HVAC system design, operation, and maintenance strategies
Research shows that controlling air relative humidity may reduce transmission of certain airborne infectious organisms.

### Possible Relative Humidity Impact

1. More humid air will slow the evaporation of large droplet into droplet nuclei.
2. Breathing dry air could cause desiccation of the nasal mucosa, making the person more susceptible to respiratory virus infections.
3. Humidity may affect the viruses’ viability or toxicity.

The ASHRAE document does not make a broad recommendation on indoor temperature and humidity. Industry practitioners should make their own decisions on a case-by-case basis.
Coronavirus and flu virus can survive longer in cold and dry environments

The transmission rates are also higher.

Issues

- Nobody knows what level of dilution ventilation is needed to decrease the droplets or droplet nuclei generated by patients to prevent their transmissions.

- It is essential to control room differential pressure (DP) and the direction of airflow. Isolation rooms should be kept at negative DP, while rooms for people with low immunity should be kept at positive DP.

- Personalized ventilation systems may prevent virus transmission through aerosols, but this has not been validated.

- Adding highly efficient particle filtration to central ventilation systems may reduce the number of infectious particles in the air.

- Two applications of Ultraviolet Germicidal Irradiation (UVGI):
  - Installation into air handlers and/or ventilating ducts
  - Irradiation of the upper air zones of occupied spaces with shielding of the lower occupied spaces
How engineers can help?

- Identify vulnerabilities with air intake, wind direction, shielding
- Identify building systems and safe zones in the general building environment
- Identify approaches to interrupting air supply to designated “shelter-in-place” locations
- Identify co-horting possibilities for pandemic situations so that whole areas of a hospital may be placed under isolation and negative pressure
# Airborne Infectious Disease Engineering Control Strategies: Occupancy Interventions and Their Priority for Application and Research

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Occupancy Categories Applicable for Consideration*</th>
<th>Application Priority</th>
<th>Research Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dilution ventilation</td>
<td>All</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Temperature and humidity</td>
<td>All except 7 and 11</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Personalized ventilation</td>
<td>1, 4, 6, 9, 10, 14</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Local exhaust</td>
<td>1, 2, 8, 14</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Central system filtration</td>
<td>All</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Local air filtration</td>
<td>1, 4, 6, 7, 8, 10</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Upper-room UVGI</td>
<td>1, 2, 3, 5, 6, 8, 9, 14</td>
<td>High</td>
<td>Highest</td>
</tr>
<tr>
<td>Duct and air-handler UVGI</td>
<td>1, 2, 3, 4, 5, 6, 8, 9, 14</td>
<td>Medium</td>
<td>Highest</td>
</tr>
<tr>
<td>In-room flow regimes</td>
<td>1, 6, 8, 9, 10, 14</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Differential pressurization</td>
<td>1, 2, 7, 8, 11, 14</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

*Occupancy Categories*

1. Health care (residential & outpatient)
2. Correctional facilities
3. Educational < age 8
4. Educational > age 8
5. Food & beverage
6. Internet café/game rooms
7. Hotel, motel, dormitory
8. Residential shelters
9. Public assembly & waiting
10. Transportation conveyances
11. Residential multifamily
12. Retail
13. Sports
14. Laboratories
Problems need to be resolved now: risk assessment of COVID-19 coronavirus transmission through aerosols in public spaces

**Urgently needed:** experiments on animals and mathematic model parameters determination

- Does it transmit through aerosols? (experiments on animals)
- The natural decay rate of the virus viability (various environments)
- Exposure threshold for virus infection (susceptibles)
- Rates of virus release by infected patients at different stages and by various activities

What is the indoor environment control parameter?

**CO₂ level between 550–1000 PPM**
Thanks

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