COVID-19 and Beyond: A Brief Introduction to Restaurant Air Quality

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COVID-19 Transmission

- SARS-CoV-2 virion are spread from an ill person to others via three very different mechanisms:

1. Sporadic cough, sneeze droplets (> 5 microns) that travel 6 feet or less;

2. Surface contamination by fomites; and

3. Continuously exhaled breath aerosols (≤ 5 microns) that can stay aloft 30 minutes or even longer and move around with air currents.

When does an infection occur

- When the inhaled dose exceeds a critical number of virions. The dose is a cumulative number which can be reached from ono or more of the three exposure mechanisms and in more than one setting, i.e. an amount inhaled at home, in transit and in the restaurant.
- The critical number of inhaled virions for 50% of humans to become ill is called the HID_{50}.
- Human immune defense system is weakened by low relative humidity.[1] The optimum relative humidity while preventing structure mold growth is 40% -45% in winter heating and 50- 60% in summer A/C season
- Neither the CoV-2 virion shedding rate for coughs, sneezing and normal breathing nor the HID_{50} for a COVID-19 infection to occur are known yet.
- Ref 1. Kudo et al. Low ambient humidity impairs barrier function and innate resistance against influenza infection. PNAS 117 (22), pp. 11875-11877. 2019.

Restaurant measures

- Served food only. No salad bars
- Meet or exceed ASHRAE restaurant ventilation standards = 10 CFM/person full capacity (7.5 CFM/p plus 0.18 CFM/SF)
- Maintain indoor relative humidity at 40-50% if possible while avoiding window and hidden perimeter wall condensation
- Provide wind breaks outdoors
- No ceiling or wall fans indoors
- Automatic opening and closing doors
- Washroom passageway entrances
- Strong washroom exhaust fans
- High ceilings indoors and outside

Measures to mitigate infection from Coughs and Sneezes

- Space tables and their chairs $>$ 6ft
- Chefs and servers must wear masks at all times and disinfect hands frequently.
- Patrons must cover mouths when coughing or sneezing

Measures to mitigate exposure to surfaces covered by fomites

- Staff separate tables and their chairs by 6 ft or more
- Staff disinfect tables and arms and backs on chairs between use by different patron groups
- Staff supply hand and surface disinfectant bottles and wipes on each table for use by patrons
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- Staff disinfect washrooms frequently
- Staff disinfect door knobs and door push plates frequently

Aerosol inhalation[2]

- $D = p\{NI/VV_e\}\{t+OD/VVe*[\exp(-VV_e t/OD)-1]\}$

- where
- D= exposed persons inhaled dose per ill
- person, virions.
- p = number of people exposed, depends on
- virion dispersion, the fewer exposed the higher
- the risk of an infection.
- N = virion shedding by an ill person
- I = inhalation rate
- V = outside air plus virus free filtered air
- Ve = ventilation efficiency = 1 for low ACH
- t = exposure time
- OD = occupancy density, spatial volume per person

Ref 2. Douglas Stuart Walkinshaw. COVID-19 and Beyond A Brief Introduction To Passenger Aircraft Cabin Air Quality. ASHRAE Journal, pp 12.-18. October 2020.

Virion shedding and HID_{50}

Influenza A as a proxy for COVID-19 (similar virion size)

- **Droplets ≥ 5 microns infected person virion shedding rate = 24,000 virions/hr; some will aerosolize depending on RH [2]**
- **Aerosols < 5 microns infected person virion shedding rate N = 76,000 virions/hr[3]**
- **HID50 = 900 to 3000 virions[4]**

- Ref 3: Yan et al. Infectious virus in exhaled breath. University of Maryland, School of Public Health and Clark School of Engineering. 2017.
- Ref 4. Nikolai Nikitin, Ekaterina Petrova, Ekaterina Trifonova, and Olga Karpova. Influenza Virus Aerosols in the Air and Their Infectiousness. Advances in Virology Volume 2014, Article ID 859090, 6 pages

Inhalation rate, I

- Sleeping 1 met [5] I = 6- 7 L/min
- Light activity 1.5 met [5] I = 8-10 L/min
- Eating thermic effect:
  - proteins I = 10- 13 L/min
  - carbs I = 9 - 11 L/min

Ref 5. US EPA. Exposure Factors Handbook, Table 6.48. 2011

Virion Aerosol Filtration

- MERV12 (78% virion removal at 40 Pa [5] =0.16 in. w.g.)
- MERV13 (90% virion removal at 50 Pa [5]
  - = 0.2 in. w.g.)
- HEPA (100% but restricts air flow thru it)

- The lower the pressure drop across the filter, the higher the virion removal efficiency

Ref 5. Study of Viral Filtration Performance of Residential HVAC Filters. JOHN ZHANG, DOUG HUNTLEY; ANDY FOX; BRYAN GERHARDT; AL VATINE,; JOHN CHERNE. ASHRAE Journal , August 2020

Illustrative Examples: Dining Group Influenza A Dose & Related Infection Risks for 1 ill person shedding these virions. (Note an individual's dose can accumulate between settings)

- Variables: 1.5-hour exposure, 9.8 ft ceiling, eating inhalation rate, I =12 L/min/person. Ventilation outside air = 10 CFM/person set for full capacity even if only partly full. N = 76,000 virions/hr;

- Example 1 Area occupancy density, AOD= 15.4 SF/person
- DOSE = 4,034 virions spread over ? People. The larger ?, the lower the # of infections
- HID_{50} = 2000 virions: 50% risk of infection ≤ 2 person
- HID_{50} = 900 virions: 50% risk of infection ≤ 4.5 persons

- Example 2 Half capacity AOD = 30.75 SF/p, (doubles V/p and OD)
- DOSE = 2,017 virions spread over ? People. The larger ?, the lower the # of infections
- $HHID_{50}$ = 2000 virions: 50% risk of infection ≤ 1 person
- HID_{50} = 900 virions: 50% risk of infection ≤ 2.2 persons

- Example 3 Half capacity AOD = 30.75 SF/p; 20 CFM/person thru MERV 13 filter
- DOSE = 814 virions dispersed over ? People. The larger ?, the lower the # of infections
- HID_{50} = 2000 virions: 50% risk of infection ≤ 0.4 persons
- HID_{50} = 900 virions: 50% risk of infection ≤ 0.9 persons

Other Measures to mitigate airborne transmission

- Outdoor dining
- High ceilings help as body heat plume rises taking with it infectious aerosols,
- Limit patron time inside the restaurant, limits dose
  - Require reservations with precise beginning and ending times,
  - Provide pre-arrival up-to-the- minute menus,
  - Provide responsive meal ordering and checking service

Douglas Stuart Walkinshaw

- Conducted DDH destroyer series superstructure measurements and analysis under air blast.
- Conducted a safety analysis of the Gentilly nuclear reactor design under a nuclear excursion.
- Managed Canadian govt technology development and energy conservation for buildings, marine structures and bridges.
- Managed the National Research Council Canada first indoor air quality research program.
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- Elected by international peers President of the 5th International Conference on Indoor Air Quality and Climate, Toronto 1990. 1000 attendees, 500 scientific peer reviewed papers.
- Led the formation of the International Society of Indoor Air Quality and Climate (ISIAQ).
- Conducted hundreds of buildings and residential indoor air quality investigations and identified the measures needed to resolve the many problems identified.
- Conducted ETS measurements which led to the banning of smoking in Canadian prisons.
- Participated on ASHRAE building and aircraft ventilation standards development committees.
- Advised the CUPE Aircraft Flight attendant division and the American Association of Flight Attendants AFA on aircraft air quality matters.
- Developed building and aircraft ventilation, moisture and humidity control technologies which have had patents granted in Canada, the USA and Europe.
- Co-invented ejector technology for the energy efficient filtration of infectious virions in passenger aircraft with patents granted in the USA and Canada.
- Advised passenger airlines and restaurants on COVID-19 infection risks and mitigation measures .