Installing, Operating, And Servicing A/C Systems With COVID-19 In Mind
United Nations Environment Programme/Ozone Action Side Event to MOP 32

ENGINEERING CONTROLS FOR AIRBORNE INFECTION RISK

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Infectious Disease Transmission Modes

- **Airborne**
  - *Droplet*
  - *Aerosol*
- **Fomite** – intermediate surface
- **Direct contact**
- **Vehicle borne** (water, food, blood)
- **Vector** (insect, animal)

...HVAC mainly impacts aerosol transmission
Sources of Infectious Aerosols

- Humans – breathing, talking, singing, coughing, sneezing
- Plumbing – toilet flushing, splashing in sinks
- Medical procedures – dentistry, endotracheal intubation, others
Respiratory Droplet Characteristics

- Droplets contain proteins and salts, dry to 20-40% of initial size
- Pathogens are incorporated in particles
- Half or more of infectious load is in particles < ~5 µm
- Small particles can stay airborne for long periods of time

US CDC and WHO recognize possible indoor airborne transmission of Covid-19
(10/5/2020)

- **COVID-19 most commonly spreads during close contact**

- **COVID-19 spreads less commonly through contact with contaminated surfaces**

- **Airborne transmission of SARS-CoV-2 can occur under special circumstances**
  - Enclosed spaces
  - Prolonged exposure to respiratory particles
  - Inadequate ventilation and air-handling

“Ventilation represents a very important aspect, a very important factor to prevent the virus from spreading indoors.”

WHI Science in 5
https://www.youtube.com/watch?v=XJC1f7F4qtc
Risk management: 
HVAC is one layer of an effective mitigation strategy

- Source elimination
  - Testing, contact tracing
- Substitution – NA
- Engineering controls
  - HVAC interventions to control aerosols
- Administrative controls
  - Rules and procedures
- Personal protective equipment
  - N95 mask – mainly protects wearer
  - Surgical/cloth masks protect others (mainly)
Engineering Controls

- Ventilation
- Air distribution
- Filtration
- Inactivation
  - Air cleaners
  - Humidity and temperature control
Ventilation with Outdoor Air

- Dilutes contaminants, increases exposure time required for exposure to an infectious dose
- Effective, but energy intensive, even with energy recovery
- Minimum required (e.g., ASHRAE 62.1) is a good baseline – must supplement with other controls
- $7-10 \text{ L/s-pers} \approx 15-20 \text{ cfm/pers}$

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[Figure 4. Associations between common cold infection rates and mean ventilation rate in winter in buildings constructed after year 1993.](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC32017956/) Proportion of occupants with $\geq 6$ common colds in the previous 12 months.

Sun, et al. (2011)
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3217956/
Air Distribution

- Strong drafts may extend distance travelled by large droplets - avoid
- Lower velocity mixing may be preferable to displacement
- Local exhaust/personal ventilation may be useful in some situations


Filtration

- High efficiency filters can remove respiratory aerosols efficiently
- For indoor sources, must have recirculation in space or through central system
- Effective if clean air delivery rate (efficiency × flow rate) is high enough
- Typical HVAC filters aren’t effective for respiratory aerosol removal – MERV 13/ePM1 50% recommended for recirculated air
- Standalone HEPA filters can supplement HVAC

Representative MERV rated filter performance (Kowalski and Bahnfleth 2002)
Inactivation – Air cleaners

- Germicidal ultraviolet light
  - *UVC damages DNA/RNA or envelope of pathogen*
  - *Well developed technology approved by US CDC for tuberculosis control*
  - *Multiple ways to use*

- Other, less proven technologies that put reactive species in air
  - *Ionizers*
  - *Dry hydrogen peroxide*
  - *Photocatalytic oxidation*

- Be sure air cleaners are:
  - *Safe*
  - *Effective for proposed application*
Inactivation
Temperature and Humidity

- Activity of viruses varies with temperature and relative humidity
- Affect susceptibility to infection
- Maintaining a minimum humidity has benefits, but difficult to implement in many buildings
- Order of magnitude lower effect than ventilation and filtration

Summary

- Engineering controls reduce airborne infection risk by reducing exposure through dilution/exhaust, capture, and inactivation
- Minimum ventilation and filtration requirements for non-healthcare facilities generally do not provide acceptable infection risk
- To achieve best outcome, combine required minimum ventilation with other controls, especially high efficiency filtration of recirculated air, to achieve control targets
- Air cleaners are an important class of controls, but available technologies have a wide range of evidence for efficacy and safety
Thank You!

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ashrae.org/covid19