Protecting Human Health Is In Your Hands (and HVAC)!

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ASHRAE Distinguished Lecturer
Epidemic Task Group Member
CEO Taylor Healthcare Consulting
Hello! I am happy to be here with you today

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Infection Control Consultant

ASHRAE Distinguished Lecturer
Epidemic Task Force
Environmental Health Committee
Presentation Summary

COVID-19 reveals an opportunity
- Our priorities have been rearranged
- The built environment and health

Studies on *Homo Indooris*
- Humans and microbes share spaces
- Humidification needs are undeniable

Buildings can and must support healthy occupants
- Driving large-scale change
COVID-19 reveals an opportunity
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My journey to you started around 1983
Non-hygienic hospital conditions, yet few infections

Wewack General Hospital, Papua New Guinea 1983
Yet, in N. America 1,700,000 patients/year get an infection from their hospitalization (HAI)
“Never underestimate the power of the environment!”

Harvard Medical School
Chief-of-Surgery,
Judah Folkman, M.D.
working with medical student, S. Taylor, 1986
Our environment (90% indoors) has become very sophisticated

<table>
<thead>
<tr>
<th>timeline:</th>
<th>10,000 BC</th>
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**Infectious diseases:**
- parasites, zoonosis
- 1st epidemics: small pox, measles, influenza, plague
- 1st pandemic: "Spanish flu"
- Introduction of antibiotics & vaccines
- Increasing infections, zoonotic transmis., ABX-resistant bacteria
However, many diseases have increased

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This is not the first, and will not be the last pandemic

Bubonic plague
1347

Spanish Influenza
1918

COVID-19
2020
The COVID-19 virus mutated, allowing attachment to our deep lung tissues, and we have no immunological defenses from prior exposure.
What options have medical professionals given us?

- Testing: availability, accuracy? (difficult to quantify)
- Vaccine or treatment: 12+ mo
- Protocols: difficult to quantify
Proper management of the building opens a whole new toolbox!
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Buildings can and must support healthy occupants
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The changing priorities of building design and operation

Past: protection from elements

Pre-COVID: energy conservation

Present: occupant health

A building’s purpose
Survival of the fittest

Occupants send their microbes into buildings

Indoor environments determine which microbes will survive and interact with occupants
Do indoor factors contribute to infections?

Study design
Compared patient room data to hospital associated infections to determine key drivers

Academic hospital: 10 rooms, 13 months, 8M datapoints
Do indoor factors contribute to infections?

**Study design**
Compared patient room data to hospital associated infections to determine key drivers

- Temperature
- Staff & visitor hand cleaning
- Room pressurization
- Lux
- CO$_2$ level
- Absolute humidity
- Relative humidity
- Room traffic
- Room air changes
- Outdoor air fractions

Academic hospital: 10 rooms, 13 months, 8M datapoints
As patient room RH went down, infections went up!

<table>
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<th>Coefficientsa</th>
<th>Beta</th>
<th>t</th>
<th>Sig</th>
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<td>Standardized Coefficients</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Beta</td>
<td>-9.060</td>
<td>-2.396</td>
<td>.020</td>
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Average RH for all patient rooms

Healthcare-Associated Infections in 10 monitored patient rooms
Infection rates were lowest when indoor RH = 40-60%
January 25 – March 11 (32 days)

Half of the classrooms were humidified, the other half were not

<table>
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<th>RH of classrooms</th>
<th>% Airborne particles carrying virus (PCR)</th>
<th>Virulence of airborne virus</th>
<th># children absent due to influenza illness</th>
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<td>20%</td>
<td>49%</td>
<td>75%</td>
<td>22</td>
</tr>
<tr>
<td>45%</td>
<td>19%</td>
<td>35%</td>
<td>9</td>
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Will this person spread her infection?
3 possible steps to intercept the spread of COVID-19 disease

1. Viral load from infected person

2. Virus Transmission

3. Vulnerability of secondary host

Behaviors

Indoor air and surface “cleanliness”

Increase health and immunity
Social distancing, hand hygiene, face masks

SOCIAL DISTANCING

2M
6 feet
3 possible steps to intercept the spread of COVID-19 disease

1. Behaviors
   Viral load from infected person

2. Indoor air and surface “cleanliness”
   Virus Transmission

3. Increase health and immunity
   Vulnerability of secondary host
Yes, SARS-CoV-2 spreads through the air

Airborne transmission of SARS-CoV-2: The world should face the reality

Lidia Morawska\textsuperscript{a,}*\textsuperscript{*}, Junji Cao\textsuperscript{b}

\textsuperscript{a} International Laboratory for Air Quality and Health (ILAQH), School of Earth of Atmospheric Sciences, Queensland University of Technology, Brisbane, Queensland 4001, Australia
\textsuperscript{b} Key Lab of Aerosol Chemistry & Physics (KLACP), Chinese Academy of Sciences, Beijing, China
Pathogen infectivity is high when RH < 40%

- Greater aerosol transmission
- Evasion from surface cleaning through resuspension
- Increased survival and virulence of pathogens
Infectious droplets shrink, travel far and evade surface cleaning when the air is dry.

**Droplet diameter in microns (um)**

- 0.5
- 1
- 3
- 10
- 100

**Distance travelled:**

- 1m
- 10m+

**Float time**

- 41 hours – 21 days
- 1.5 hours
- 6 seconds
Influenza A virus is more infectious when RH is below 40% 

Noti 2007
Humidification to 50% RH reduces the viable Coronavirus to less than 1% in 2 days, significantly decreasing the infection risk (blue line).

- RH 20%, T 20°C: inactivation log$_{10}$ - 0.081/day
- RH 80%, T 20°C: inactivation log$_{10}$ - 0.212/day
- RH 50%, T 20°C: inactivation log$_{10}$ - 0.896/day
RH affects infectivity, contact & aerosol transmission of viruses

Transmission risk of respiratory viruses in increasing RH shows an asymmetric U curve.
3 possible steps to intercept the spread of COVID-19 disease

1. Behaviors
   Viral load from infected person

2. Indoor air and surface “cleanliness”
   Virus Transmission

3. Increase health and immunity
   Vulnerability of secondary host
Low humidity impairs our immune defenses against influenza infection


This study was done in genetically engineered mice
How does our body protect us from respiratory infections?

Influenza virus

Influenza virus is spread from infected people by coughs or sneezes.
A healthy immune system provides protection

1. **Physical barrier**: Mucus production and ciliary clearance

First line of defense against pathogens
A healthy immune system provides protection

1. **Physical barrier**: Mucus production and ciliary clearance

2. **Innate immune responses**:
   Type I IFN and Interferon stimulated genes (ISGs)

- **Interferon**
- **Dendritic cell**
- **Activate**
- **Macrophage**
- **T cell**
- **B cell**
All of these protective mechanisms are impaired at RH 20% and are optimal at 50% RH.
RH 40–60% decreases disease transmission in two ways

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<th>Indoor air and surface “cleanliness”</th>
<th>Strengthen immunity</th>
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ASHRAE 1985: “Optimal RH Level For Health” = 40%–60%
Do you have any new ideas about these low infection rates?

1. Optimal RH levels
2. People have healthy immune systems
3. No selection for pathogenic microbes
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**We can correct this trend**

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**Start with proper indoor RH 40–60%**

- primitive housing
- simple sanitation
- industrial revolution: central sewage & water systems
- post-industrial: cities, tighter buildings, dryer and warmer indoor air

**Infectious diseases:**

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- increasing zoonotic transmis., ABX-resistant bacteria

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Conclusions: COVID-19 is a “Wake-Up Call”

1. Using occupant health as a lens to view the indoor environment, we have learned that IAQ is powerful.

2. Low relative humidity is harmful to people and benefits pathogens (bad microbes).

3. We must design and operate buildings to support occupant health, and the first step is proper indoor humidification.
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phone: (860) 501-8950

and Luigi!
Partial Bibliography

• Gibbons SM. 2016, The built environment is a microbial wasteland, mSystems 1(2):e00033-16. d
• Stone W et al, 2016, Microbes at Surface-Air Interfaces: The Metabolic Harnessing of Relative Humidity, Surface Hygroscopicity, and Oligotrophy for Resilience, frontiers in Microbiology 7:1563. doi: 10.3389/fmicb.2016.01563
• Helsinki alert of biodiversity and health, Annals of Medicine, 2015
• Vandegrift R et al, 2017, Cleanliness in context: reconciling hygiene with a modern microbial perspective, Microbiome (2017) 5:76
• Kramer A et al, 2006, How long do nosocomial pathogens persist on inanimate surfaces, a systematic review, BMC Infectious Diseases 2006, 6:130
• Tropical Medicine & International Health. 2008., Volume 13, Issue 12, pages 1543-1552, 6 Oct.
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