Humidity, Human Health and Implications in improving Health Care

Presenter: Steve Brandt, P.E.

Developed from research conducted by Stephanie Taylor, MD
Stephanie Taylor, MD, M Arch, FRSPH

- Harvard trained physician
- 30 year medical career as pediatric oncologist
- 10 years ago obtained master’s in architecture
- Today- President of Taylor Healthcare Consulting
- Consultant to Nortec Humidification Technologies
Objectives

Recognize:

- The relationship between relative humidity and microbial viability
- How the body’s ability to prevent infection is impacted by dry air
- Particle size, settling rates and increased pathogen exposure
- In-Hospital infectious disease control study and the financial impact of Hospital Acquired Infections (HAI)
Sterling-Scofield Diagram

The diagram illustrates the relationship between relative humidity and the growth of various microorganisms and conditions, highlighting the optimum zone.

- **Bacteria**
- **Viruses**
- **Fungl/Mold**
- **Dust Mites**
- **Respiratory Infections**
- **Allergic Rhinitis & Asthma**
- **Ozone Production**

The optimum zone is marked by a green band indicating the ideal relative humidity range for minimizing the growth of these entities.
**Viruses:** Common cold, Influenza, Measles, Bronchitis, SARS

**Bacteria:** Rheumatic fever, Otitis media, Carditis, Diphtheria, Whooping cough, Tuberculosis, MRSA, Meningitis and Q-fever

**Fungi:** Histoplasmosis, Coccidiomycosis and Blastomycosis

**Antigens:** Toxins that induce immune responses in the body, causing Allergic diseases of hypersensitivity pneumonitis (HP), Allergic asthma, Rhinitis and Pergillosis
At 40%-60 indoor RH

building occupants are healthier

- fewer infections
- fewer allergic reactions
- less fatigue and better cognitive functioning
- higher school attendance and performance
- higher employee productivity
How far will this sneeze travel?
It depends on the size of the aerosols
At 40%-60 indoor RH

droplets produced by sneezing, flushing toilets, etc settle quickly

“Moisture content in the air may, indeed, be the most important environmental factor influencing the survival of microbes”.

Dimmick, Naval Biological laboratory, Univ. CA, Berkeley
Fate of expelled bio-aerosols in air

- Will this cough infect others?

after cough, before established homeostasis with room air

Droplet in 50% RH

< 30% RH
• Humidity and particle size

Aerosol size and density influences settling time and longevity

Viruses
0.02- 0.4µ

Bacteria
0.3- 60 µ

Mold Spores
10-30µ

Particle Settling in Still Air

Time to settle 5 feet by unit density spheres

0.5 µm: 41 hours
1 µm: 12 hours
3 µm: 1.5 hours
10 µm: 8.2 minutes
100 µm: 5.8 seconds
transmission of infections in the indoor environment is dependent upon six factors

1. the number of people producing infectious droplets
2. the vulnerability of the secondary hosts (people)
3. the length of the occupant’s exposure
4. the ventilation rate
5. the settling rate of infectious aerosols
6. the survival of pathogens in aerosols during transmission
How sick we become depends on how deep the “bugs” go.
- Humidity decreases infections
50% RH

30% RH

Humidity decreases infections

mucus and cilia stopped
• Indoor RH < 20 %
At 40%-60 indoor RH

droplets expelled by sneezing, talking, flushing toilets, etc settle quickly

Bacteria or virus are expelled into the hospital environment in droplets

Pathogens are removed from surfaces during room cleaning

Ventilation Duct

Airborne spread to other in-patients is halted, resulting in fewer HAIs.
RH and infection control

Which of these factors is influenced by RH?

1. the number of people producing infectious droplets
2. the vulnerability of the secondary hosts (people)
3. the length of the occupant’s exposure
4. the ventilation rate
5. the settling rate of infectious aerosols
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• Microbes hate humidity

Humidity above 40% inactivates ≈ 80% of Influenza Viruses within 15 minutes

Graph showing relationship between relative humidity (% at 20°C) and virus viability (%).
Microbial Activity Chart
Takeaways

• Microbial viability is not further reduced at room ambient (20°C) RH above 45%

• Increasing RH from 35% to 40% reduces microbial viability by 64%
What’s the annual cost to humidify from 35% to 40% at 20°C?

Per 100,000 cfm:

$34,000

4800 annual bin hours
$1.25/therm
60% net steam delivery efficiency
Thinking, productivity and RH

• Humans need humidity
Simple respiration in a dry environment—In the absence of workload—can result in the water loss of up to 1 liter per day and is recognized as “invisible transpiration.” Dehydration levels of 1% body weight adversely affects cognitive performance.

- Dry air reduces cognitive function

20% RH

40-60% RH

The effects of water loss can be pronounced for flight crewmembers operating in the dry environment of high altitudes; therefore, crewmembers should ensure that they drink adequate amounts of water and should try to avoid situations that deplete the body’s supply of water.
• Humidity and cleaning

Surface cleaning is less effective in dry air

- microbes are re-suspended
- spread through ventilation systems
- infect more people
Hospital Patients and humidity

STUDY: Colonization and Succession of Hospital-Associated Microbiota
Simon Lax, Daniel Smith, Naseer Sangwan, Kim Handley, Peter Larsen, Miles Richardson, Stephanie Taylor, Emily Landon, John Alverdy, Jeffrey Siegel, Brent Stephens, Rob Knight, Jack A Gilbert, In press, 2016
In- Hospital Infectious Disease Control Study

- Built 2013, LEED Silver
- 1.2 million square feet
- 100,000 square feet per floor
- 240 single-occupancy inpatient rooms
- 52 ICU beds
- 28 ORs
- Levels 8, 9, 10 - surgical, oncology and transplant patient rooms
- Green roof
- Northern climate
10 pt rooms
2 RN stations
Collect information on the patient room environment

- Staff hand hygiene
- Temp
- Lux
- \( \text{CO}_2 \)
- RAC
- RH, absolute humidity
- Outdoor air fractions
- Room pressurization
- Traffic
Pt. Room vs Pt. Outcome

- monitor the physical environment
- measure the microbial footprint - PCR
- determine patient HAIs and length of stay
• Results: RH in Patient Rooms

Colonization and Succession of Hospital-Associated Microbiota
In press, 2016
Results: Indoor RH and Patient HAIs

- Avg RH for all patient rooms
- Healthcare-Associated Infections in 10 monitored patient rooms
As RH goes, infections go.
Colonization and Succession of Hospital-Associated Microbiota
In press, 2016
As RH goes down, bacteria spread.
## Summary of Total Excess Costs and Hospital Days Due to Hospital Acquired Infections

<table>
<thead>
<tr>
<th>Infection Type</th>
<th>Total Infections</th>
<th>Total Excess Costs</th>
<th>Total Excess Hospital Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urinary Tract Infections</td>
<td>1,296</td>
<td>$1,435,968</td>
<td>2592.0</td>
</tr>
<tr>
<td>Surgical Wound Infections</td>
<td>365</td>
<td>$7,042,464</td>
<td>4378.0</td>
</tr>
<tr>
<td>CRBSI</td>
<td>148</td>
<td>$4,990,636</td>
<td>2509.0</td>
</tr>
<tr>
<td>VAP</td>
<td>15</td>
<td>$401,369</td>
<td>170.0</td>
</tr>
<tr>
<td>MRSA</td>
<td>120</td>
<td>$927,162</td>
<td>646.0</td>
</tr>
<tr>
<td>CDIFF</td>
<td>122</td>
<td>$500,200</td>
<td>733.0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>2,066</strong></td>
<td><strong>$15,297,799</strong></td>
<td><strong>11,028.0</strong></td>
</tr>
</tbody>
</table>
Total Excess, Non-reimbursable Costs from HAI in 1 Year:

- UTI: $1,435,968
- SSI: $7,042,464
- CRBSI: $4,990,636
- VAP: $401,369
- MRSA: $927,162
- CDIFF: $500,200
The Centers for Medicare and Medicaid Services (CMS) does not reimburse hospitals for patient readmissions within 30 days of original discharge – currently the readmission rate nationally is 14-20%.
In summary

Humidified air

- decreases respiratory and skin infections
- supports healthy skin & wound healing
- improves cognitive performance
- supports surface cleaning
• Optimize building management

for people …

- Design ventilation systems in occupied spaces to maintain RH between 40-60%
- Control temperature and pressure variations throughout the building and during season changes
- Maintain surface cleaning for infection control

for building components…

- Expand surveillance for mold in hidden spaces
- Prevent condensation points in walls and ceilings
- Choose optimal humidification systems
How does weather impact the onset and spread of influenza?
• Influenza by month

Seasonal distribution
Flu cases soar in Onondaga County and statewide

Syracuse, N.Y. — Flu cases soared in Onondaga County and across the state during the week ending Dec. 27.

Onondaga County reported 127 lab-confirmed flu cases, up from 43 the previous week. So far this season, the county has received reports of 211 flu cases, nearly five times more than the number of cases reported for the same period of 2014.

Those numbers represent the tip of the iceberg because most people who get the flu do not get tested, according to public health officials.

The report for the week ending Dec. 27 is the latest data available on local and statewide flu activity.

The state Health Department reported 3,922 lab-confirmed cases, up 90 percent from the previous week.
Positive Influenza Laboratory Results reported to NYSDOH, by Week, 2015-16 (N=48,639)

- Influenza Type Not Specified
- Influenza B
- Influenza A

"Week ending Dec 27
NYSDOH reported
3922 cases"
Weather data skewed to the right to coincide with reported cases for week ending 12/27 at December 2016 average humidity ratio.
Positive Influenza Laboratory Results reported to NYSDOH, by Week, 2014-15 (N=50,406)

WEATHER DATA: ASHRAE WEATHERDATA VIEWER, STATION: SYRACUSE, NY
Positive Influenza Laboratory Results reported to NYSDOH, by Week, 2013-14 (N=37,065)

- Influenza Type Not Specified
- Influenza B
- Influenza A

Number of Reports

Week Ending

5-Oct, 19-Oct, 2-Nov, 16-Nov, 30-Nov, 14-Dec, 28-Dec, 11-Jan, 25-Jan, 8-Feb, 22-Feb, 8-Mar, 22-Mar, 5-Apr, 19-Apr, 3-May, 17-May, 31-May
# Humidity Ratio and Influenza Onset

Seasonal Flu “Launch Point”

<table>
<thead>
<tr>
<th>Flu Season</th>
<th>grains/lb dry air</th>
<th>week over week reported case increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015-2016</td>
<td>38</td>
<td>54%</td>
</tr>
<tr>
<td>2014-2015</td>
<td>36</td>
<td>75%</td>
</tr>
<tr>
<td>2013-2014</td>
<td>36</td>
<td>56%</td>
</tr>
<tr>
<td>2012-2013</td>
<td>38</td>
<td>55%</td>
</tr>
</tbody>
</table>
Pass / Fail

• What room ambient relative humidity level inactivates 80% of microbes within 15 minutes?
Pass / Fail

• What room ambient (20°C) relative humidity level inactivates 80% of microbes within 15 minutes?

• ANSWER- 40%
Pass / Fail

• Infectious droplet particle size impacts which of the following

  – a. Settling Rate
  – b. Infection Potential
  – c. the survival of pathogens in aerosols during transmission
Pass / Fail

• Infectious droplet particle size impacts which of the following
  
  – a. Settling Rate
  – b. Infection Potential
  – c. the survival of pathogens in aerosols during transmission

• ANSWER- All of the above
Pass / Fail

• When will this season’s influenza launch point occur?
Pass / Fail

• When will this season’s influenza launch point occur?

• ANSWER- When Wayne Mahar says the humidity ratio today hit 37 gr/lb (+/- 1)