Putting People First: The Healing Power of Indoor Air

October 7 | Presented by Stephanie Taylor, M.D.

2019 NYS Healthcare Facilities Conference
Presented by
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Harvard Medical School, Primary Care
CEO Taylor Healthcare Consulting

and, Luigi
The past

- Human health and lifestyle
- What happens in a hospital, stays in a hospital

The present

- New tools shed light on people and buildings
- Survival of the fittest

The future

- Our assumptions are killing us
- Call to action
Presentation Summary

The past
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In 1858, Florence Nightingale documented high rates of hospital-associated infections.

*Zymotic* = Epidemic, endemic, and contagious diseases:
1) Air or water-borne
2) Contact/inoculation
3) Diet
4) Parrotic
- Farr, Annual Reports 1842, 1856
2019 "What happens in a hospital, stays in a hospital"

Hospital reported = 4

AHRQ tool = 35

IHI Trigger tool = 354

ADVERSE EVENTS = 393
It’s not just HAIs, many diseases are on the rise
Domesticated dogs are now carriers of the quickly evolving H3N2 influenza virus.
We have become *Homo Indooris*

“We shape our buildings, then they kill us!” - Dr. Dickerman

- Open dwellings
- Outdoor air exchange
- Tight building envelopes
- Mechanical air ventilation systems
## Co-evolution of human lifestyles and infectious diseases in Europe

<table>
<thead>
<tr>
<th>social system</th>
<th>rural villages, agricultural society,</th>
<th>first cities close to animal husbandry</th>
<th>simple sanitation, in rural areas</th>
<th>medieval cities, rural</th>
<th>industrial revolution agrarian, rural → industrial &amp; urban society</th>
<th>post-industrial mega-cities, skyscraper mobility boom</th>
</tr>
</thead>
<tbody>
<tr>
<td>timeline</td>
<td>350'000 BC</td>
<td>10'000 BC</td>
<td>5'000 BC</td>
<td>800 BC - 500 AC</td>
<td>1500 AC</td>
<td>1900 AC</td>
</tr>
<tr>
<td>housing</td>
<td>primitive housing</td>
<td>simple houses no sanitation</td>
<td></td>
<td>running water, sewage systems, central heating, electricity light (windows, glass)</td>
<td>insulated houses automation &amp; control</td>
<td>Up dryness &amp; indoor temperature</td>
</tr>
<tr>
<td>dominant infectious diseases</td>
<td>parasites, zoonosis</td>
<td>1st epidemics: small pox, measles, influenza</td>
<td>1st plague epidemic</td>
<td>recurrent epidemics &amp; plague</td>
<td>1st pandemic “Spanish flu” introduction of antibiotics &amp; vaccines</td>
<td>Increasing infections, revival of zoonotic infections (avian flu)</td>
</tr>
</tbody>
</table>

### Co-evolution of human lifestyles and infectious diseases in Europe

- **350’000 BC**: First appearance of humans in Europe, primitive housing with no sanitation.
- **10’000 BC**: Agricultural revolution, simple houses with no sanitation.
- **5’000 BC**: First cities close to animal husbandry, simple sanitation in rural areas.
- **800 BC - 500 AC**: Rural sanitation improves, animal husbandry.
- **1500 AC**: Medieval cities, rural sanitation improves, animal husbandry.
- **1900 AC**: Industrial revolution, rural to industrial & urban society, running water, sewage systems, central heating, electricity light.
- **2018**: Post-industrial mega-cities, skyscraper mobility boom, insulated houses, automation & control.

### Housing

- **Primitive housing**: No sanitation, simple houses.
- **Insulated houses**: Automation & control, dryness & indoor temperature.

### Dominant Infectious Diseases

- **1st epidemics**: Small pox, measles, influenza.
- **1st plague epidemic**: Recurrent epidemics & plague.
- **1st pandemic “Spanish flu”**: Introduction of antibiotics & vaccines.
- **Increasing infections**: Revival of zoonotic infections (avian flu), antibiotic resistant bacteria.

### Number of Infectious Diseases

Co-evolution of human lifestyles and infectious diseases in Europe.
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Tissue culture methods → limited insight into the microbial world

Here humans → exposure → infectious disease → pathogens only found

There microbes

undiscovered microbes
the vast majority of microbes are harmless and beneficial for humans and the ecosystem.
Healthy microbial communities need diversity

- Healthy: Balanced microbiome
- Unhealthy: Un-balanced microbiome

**diversity** balanced microbiome

**monotony** un-balanced microbiome
by naked eye we see nothing!

by microscopy we can detect thousands of microbes

genome sequencing has uncovered trillions of microbes that inhabit our buildings

Buildings also have their own microbiome
A closer look at our surroundings
The indoor environment now drives natural selection

Occupants send microbes into buildings

Building design, use and ventilation “select” microbes which survive and interact with occupants
Microbes in mechanically ventilated buildings are more closely related to pathogens.

Mechanically ventilated
- **Low** bacterial diversity
- **High** average pathogenicity

Outdoor Air
- **High** bacterial diversity
- **Low** average pathogenicity
One year-long study to evaluate the patient room environment and HAIs

Patient room data VS. Patient HAI

- Staff & visitor hand cleaning
- Temperature
- Room pressurization
- Lux
- CO₂ level
- Relative humidity, Absolute humidity
- Room traffic
- Room air changes
- Outdoor air fractions

8 million room data points ~ 300 patient outcomes

<table>
<thead>
<tr>
<th>Room</th>
<th>Clinical symptoms</th>
<th>HAI Organisms (if indicated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>xx pneumonia, viremia</td>
<td>Pseudomonas, Epstein-Barr virus</td>
<td></td>
</tr>
<tr>
<td>xx pneumonia</td>
<td>Staphylococcus aureus</td>
<td></td>
</tr>
<tr>
<td>xx open wound of head, neck, and trunk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>xx bacteremia, organism unspecified</td>
<td>Citrobacter infection</td>
<td></td>
</tr>
<tr>
<td>xx infection due to vascular device</td>
<td></td>
<td></td>
</tr>
<tr>
<td>xx cellulitis</td>
<td>Staphylococcus aureus</td>
<td></td>
</tr>
<tr>
<td>xx sepsis, cellulitis, abscess</td>
<td></td>
<td></td>
</tr>
<tr>
<td>xx bacteremia, organism unspecified</td>
<td></td>
<td></td>
</tr>
<tr>
<td>xx pneumonia, organism unspecified</td>
<td></td>
<td></td>
</tr>
<tr>
<td>xx fever; bacteremia, organism unspecified</td>
<td></td>
<td></td>
</tr>
<tr>
<td>xx viremia</td>
<td>Cytomegalovirus (CMV)</td>
<td></td>
</tr>
<tr>
<td>xx wound infection after surgery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>xx urosepsis, organism unspecified</td>
<td></td>
<td></td>
</tr>
<tr>
<td>xx sepsis following cardiac surgery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>xx pneumonia, organism unspecified</td>
<td></td>
<td></td>
</tr>
<tr>
<td>xx infection of skin and subcutaneous tissue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>xx colitis and diarrhea</td>
<td>Clostridium difficile</td>
<td></td>
</tr>
<tr>
<td>xx wound infection after surgery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>xx urosepsis, organism unspecified</td>
<td></td>
<td></td>
</tr>
<tr>
<td>xx diarrhea</td>
<td>salmonella enteritis</td>
<td></td>
</tr>
</tbody>
</table>
As patient room RH went down, HAIs went up!
Infection rates were lowest when indoor RH = 40-60% in a long-term care facility (over 4 yrs)
2018 study: Humidity decreased Influenza A illness in a preschool

January 25 – March 11 (32 days)

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

<table>
<thead>
<tr>
<th>RH of classrooms</th>
<th>% Airborne particles carrying virus (PCR)</th>
<th>Virulence of airborne virus (% cells infected)</th>
<th># children absent due to influenza illness</th>
</tr>
</thead>
<tbody>
<tr>
<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>
</tr>
</tbody>
</table>
When RH < 40%, pathogen infectivity is high

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

**Droplet diameter in microns (um)**
- 100
- 10
- 3
- 1
- 0.5

**Float time**
- 41 hours – 21 days
- 1.5 hours
- 6 seconds

**Distance travelled:**
- 1m
- 10m+
C. diff can travel in infectious aerosols

- C-Diff seeded in a toilet
- Water samples, settle plates, and air samples
- Droplet nuclei spore bioaerosol produced over more than 24 flushes

December 2018 – American Journal of Infection Control
Contact precautions have *not* been shown to effectively reduce transmission in most patients with MRSA and VRE

When full contact precautions were stopped:

- No significant increase in transmission rates

- The health system saved approx. $643,776 and 45,277 hours per year in healthcare worker time previously spent on donning and doffing personal protective equipment

Martin, E., *Infection Control & Hospital Epidemiology*
The OR sterile field is affected by room temperature, air velocity, & RH.
Transmission of bacteria in the OR is higher in low RH

Buoyancy forces acting on internally generated particles change based on relative humidity or water vapor content in the air.

The sterile field was less contaminated in OR with RH 35% vs 20%

Greeley, D Indiana Medical Center, 2018
Influenza A virus is more infectious when RH is below 40%
Studies on the preventive effect of humidification

<table>
<thead>
<tr>
<th>Historic Studies* and Data</th>
<th>Rel. Humidity % (RH)</th>
<th>% Work Day Loss</th>
<th>Δ%</th>
<th>25 Winter Periods (inconsistent because too small ARR)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ritzen</strong>, 1966**&lt;br&gt;C4, Basel</td>
<td>40 / 49 9%</td>
<td>5.7 / 3</td>
<td>1.7</td>
<td></td>
<td>% Days Missed due to RTI, RTI by Teachers Report</td>
</tr>
<tr>
<td><strong>Sale</strong>, 1970&lt;br&gt;CA, Norfolk</td>
<td>30 / 50 20%</td>
<td></td>
<td></td>
<td>1</td>
<td>% Days Missed due to RTI, RTI diagnosed by Teachers, Parents, Doctors</td>
</tr>
<tr>
<td><strong>Green</strong>, 1975&lt;br&gt;CA, Saskatoon</td>
<td>22 / 31 5%</td>
<td>5.30 / 3.99</td>
<td>1.34</td>
<td>3</td>
<td>Days Missed lower in humidified schools</td>
</tr>
<tr>
<td><strong>Green</strong>, 1985&lt;br&gt;CA, Saskatoon</td>
<td>22 / 25 9%</td>
<td>5.03 / 4.20</td>
<td>0.83</td>
<td>11</td>
<td>Days Misses constantly lower in Schools with Humidifier</td>
</tr>
<tr>
<td><strong>Green</strong>, 1981&lt;br&gt;CA, Saskatoon</td>
<td>20 / 40 20%</td>
<td></td>
<td></td>
<td>3</td>
<td>Winter 1973-74 3R TIs too small</td>
</tr>
</tbody>
</table>

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**Notes and Footnotes:**

* Three Studies (Ser, Gubener, Salstoff) are discussed in the paper but not included in Table.

**Abbreviations:** RH = Relative Humidity, no H/w. H. = no H. with Humidification, RTI = Respiratory Tract Infection.

Δ% = Percentage Difference of Days Missed, Adjustment for Working Days not possible (missing of detailed information).

Text/Figures highlighted yellow - Figures consistent, significant Difference (p < 0.01).

Text/Figures highlighted blue - Figures inconsistent, Difference not significant, ΔRH to small.

Average Reduction on % Work/School Days Missed and (ARR) : Children 2.4% (41%), Students 0.5-0.92% (9.8-19%), Adults 0.48% (21%).
More studies

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Schaffer [21]</td>
<td>RH: 20, 30, 40, 50, 60, 70, 80 T: 21.0</td>
<td>VPA**</td>
<td>208l chamber dual stirred no tracer</td>
<td>Salt = 9.88 g/l protein 0.5 – 1.5 g/l</td>
<td>20 50 70-80</td>
<td>60 m</td>
<td>0.1 0.1</td>
<td>Many data points, all runs show lowest recovery rate in intermediate and highest in low and high RH</td>
</tr>
<tr>
<td>Sheehman [20]</td>
<td>RH: 30-34, 41-45 50-54 58-60, 66-70 T: unknown</td>
<td>Mice (lung histology) Storage &amp; Exposure Chamber (Leif Kruger) Nasal &amp; Aerosol Exposure of Mice</td>
<td>Salt = 13.6 g/l protein = 1 g/l</td>
<td></td>
<td>30-34 58-60 66-70</td>
<td>1 hour</td>
<td>0.9 10.4</td>
<td>High recovery rates at elevated RH indicate no settling losses in storage chamber</td>
</tr>
<tr>
<td>Lester [23]</td>
<td>RH: 23-80 T: 22.0-24.0</td>
<td>Mice (% of lung lesions*) death rate</td>
<td>Test room 18 m³, high-speed fan, no tracer aerosol exposure of mice</td>
<td>Salt: 10 g/l protein 10 g/l</td>
<td>30 50 80</td>
<td>100* 25.8* 100*</td>
<td>0.9 22.5 100*</td>
<td>Inhaled IV A dose that killed 100% mice at 30 &amp; 80% RH, killed only 22.5% at 50% RH, but 100% when salt free</td>
</tr>
<tr>
<td>Hood [24]</td>
<td>RH: 15-21, 52-55 78-85 T: 22.0-25.0</td>
<td>VPA**</td>
<td>Rotating drum 500 l</td>
<td>Similar solutes as Harper</td>
<td>15-21 52-55 78-85</td>
<td>20h 2h 2h</td>
<td>12 1 4</td>
<td>Lowest recovery rate at intermediate RH, highest at low and high RH, similar results with IV Singapore A2</td>
</tr>
<tr>
<td>Harper [28]</td>
<td>RH: 20-22, 34-36, 50-51, 64-65, 81 T: 20.5-24.0</td>
<td>VPA**</td>
<td>Rotating drum (74), 3 r.p.m., radioactive tracer</td>
<td>Salt = 2.2 g/l protein = 1.9 g/l</td>
<td>20-22 64-65 81</td>
<td>1 hour</td>
<td>64 15 13</td>
<td>Although rotating drum and tracers used, low virus recovery in high RH, result confusing, no explanation</td>
</tr>
<tr>
<td>Hemmes [29]</td>
<td>RH: 13, 25, 30, 33, 47, 49 68, 70, 78, 82, 90 T: 20</td>
<td>VPA**</td>
<td>4 m³ test room, circulation air (fan), no tracer used</td>
<td>Salt = 2.3 g/l protein = 10 g/l</td>
<td>30-40 60-70</td>
<td>30 minutes</td>
<td>10 0.001 r.d.</td>
<td>Extremely low recovery after 30 m indicates settling loss, no tracers used, low salt content</td>
</tr>
</tbody>
</table>
Did the very low RH in the airplane cabin contribute to this?

“Yes, she was vaccinated!

“Flight attendant in Hospital After Deadly Infection Spreads Onboard” April 7, 2019
✓Yes, she was vaccinated!
desert-like humidity on long-haul flights – a systematically underestimated risk ....

On board of aircrafts absolute air humidity is 3-4 g/kg, depending mainly on the seat load factor.

Source of graphs: Building to Suite the Climate, Birkhäuser, Basel, 2012
Altered bacterial behavior during air-transmission

- Increased antibiotic resistance
- Enhanced efficiency of horizontal gene transfer
- Increased infectivity
- Higher secretion of toxins (i.e. C. diff)
- Thickened cellular envelope – more resistant to hand gels
"Antibiotic Resistance Can Spread Through The Air, Scientists Warn, And Yes - You Should Be Terrified"

*July 26, 2018*

Dry conditions increase **horizontal** transfer of antibiotic resistance genes.
The majority of bacteria causing HAIs are resistant to dryness and survive in the air

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Persistence</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acinetobacter supp.</td>
<td>3 d up to 5 months</td>
<td>6</td>
</tr>
<tr>
<td>Clostridium difficile (spores)</td>
<td>5 months</td>
<td>3</td>
</tr>
<tr>
<td>Escherichia coli</td>
<td>1.5 h up to 16 months</td>
<td>10</td>
</tr>
<tr>
<td>Enterokokkus supp. inkl. VRE und VSE</td>
<td>5 d up to 4 months</td>
<td>4</td>
</tr>
<tr>
<td>Klebsiella supp.</td>
<td>2 h up to &gt;30 months</td>
<td>5</td>
</tr>
<tr>
<td>Pseudomonas aeruginosa</td>
<td>6 h up to 16 months</td>
<td>7</td>
</tr>
<tr>
<td>Staphylococcus aureus, inkl. MRSA</td>
<td>7 d up to 7 month</td>
<td>6</td>
</tr>
</tbody>
</table>

reaction to hospital’s dry environment → increased infectivity

Hospital surfaces are dry and non-porous

Kramer A et al. How long do nosocomial pathogens persist on inanimate surfaces? a systematic review, BMC Infectious Diseases 2006, 6:130
Enough about microbes. How do humans do in dry air?

When RH<40%, humans suffer!

**Brain**
- decreased function
- fatigue
- anxiety, depression

**Eyes**
- dry eyes
- blurry vision
- corneal inflammation

**Respiratory tract**
- infections
- allergies
- asthma

**Skin**
- dryness, cracking
- dermatitis
- auto-immune disease
“Low ambient humidity impairs barrier function and innate resistance against influenza infection”

*Proceedings of the National Academy of Sciences, USA. May 19, 2019*

Eriko Kudo, Eric Song, Laura Yockey, Tasfia Rakib, Patrick Wong, Robert Homer, Akiko Iwasaki
Question investigated: Why do these differences exist?

- RH 50% gets rid of the virus
- RH 50% gets a little sick
- RH 20% gets very sick
MX1 mice have functional Type I IFN responses.

Chamber conditions:
- Temp = 20°C
- 20%RH, 3g/m³ AH or 50%RH, 9g/m³ AH

Study setup:
- Precondition: 5 days
- Post-infection: 7 days
- Intranasal Influenza Challenge
- *Remove from chamber
Dry inhaled air causes:

- Increased susceptibility to infections
- Increased wheezing from allergic disease

RH 20% impairs first-line respiratory system defense
RH 20% impairs muco-ciliary clearance

20% RH

50% RH
Additional innate respiratory protective mechanisms are optimal at 50% RH, and impaired at RH 20%
Skin changes in dry air are the beginning of inflammatory and allergic processes.
GSA: Wellbuilt for Wellbeing

1. Mobile IEQ Node
2. Heart-Rate Variability + Activity
3. Survey App
4. Stationary IEQ Nodes
5. Static spatial attributes
Stress is lower within 30-60% RH zone, in any season.
Connecting RH, stress response, & sleep

Workplace variables

Humidity (comfort range vs outside comfort range)

Objective stress (at the office)

Sleep quality (sensor based)

Demographics

Age, Gender, BMI

Stress at the office

Wellbeing outside the office
These data associate low RH in the daytime with poor sleep at night. *Optimum 45% RH*
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ASHRAE 1985: "Optimal RH Level For Health" = 40%–60%
35 years later..... Taylor Chart 2019

- Virus (lipid membrane):
  - influenza, coronavirus, RSV, parainfl.
  - measles, rubella, herpes

- Virus (non-lipid membrane)

- Bacteria (Gram neg)

- Legionella (aerosolized)

- Bacteria (Gram pos)

- Mycoplasma (no cell wall)

- Adult in-patients (acute care)

- Elderly patients in long-term care

- Pre-school children

- Employee productivity

- Employee sleep quality

- Student learning

- Relative Humidity (%)
Why do we still keep our indoor environment so dry?
The great indoor air RH debate!

- **Buildings don’t care about humidity**
  - The drier the air the better
  - Easier to dry the air than fix the envelope construction
  - We hate humidifiers!!

- **Occupants need RH between 40% and 60% for health**
  - Decreased infections
  - Fewer allergies
  - Improved hydration
  - Improved wound healing
  - Increased work performance
The indoor microbiome adapts to available water - it’s response to dryness is contrary to what we think.

**ENGINEERS THINK**

Keeping buildings dry is a strategy for eliminating microbes and preventing health problems.

**ENGINEERS KNOW**

Dampness creates an un-balanced microbiome, dominated by mold & bacteria.

- **low RH**
  - low $w_a$ (water activity)
  - highest diversity
  - lowest risk

- **intermediate RH**
  - water activity ($w_a$)

- **high RH**
  - high $w_a$
  - dampness creates an un-balanced microbiome, dominated by mold & bacteria

- **low $w_a$**
- **high $w_a$**

This is not correct!
They care about water activity!

Fungi don't care about humidity!

They care about water activity!
Building insulation largely determines the presence of liquid water and mold growth.

<table>
<thead>
<tr>
<th>good insulation properties</th>
<th>bad insulation properties</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>outside</strong></td>
<td>14 °F</td>
</tr>
<tr>
<td><strong>outside building shell boundary layer room air</strong></td>
<td>14 °F</td>
</tr>
</tbody>
</table>

R-value = 2.0 W/m²K  
R-value = 0.25 W/m²K

With identical temperatures of outside and inside air, differences in insulation techniques largely determine the amount of condensation present. **Capillary Condensation Also Matters!**

Inside wall condensation would require indoor RH of > 95%  
Inside wall condensation starts with a indoor RH of 35%. With outdoor temperature of 14°F the dew point is easily reached on inner wall surfaces.
What motivates people to listen?
Humidification is used when the financial impact is quantifiable.

National Institute of Health animal facility

Replacement cost of a primate: $22,000

40%–60% RH

NASA spacecraft

Cost to train an astronaut: $50 million (in 2006)

40%–60% RH

Louvre

Mona Lisa value: $780 million

40%–60% RH
Do humans have a dollar value?
These humans are worthy of humidification.
These humans are worthy of humidification.

“Arrrgghh, Why didn’t we humidify our air sooner?!?”
HAIs are costly for a 250 bed hospital

<table>
<thead>
<tr>
<th></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>2,592.0</td>
</tr>
<tr>
<td>Surgical Wound Infections</td>
<td>365</td>
<td>$7,042,464</td>
<td>4,378.0</td>
</tr>
<tr>
<td>CRBSI</td>
<td>148</td>
<td>$4,990,636</td>
<td>2,509.0</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>

*2015 volume of a selected 250-bed hospital, APIC calculated costs*
Value analysis of humidification in 250-bed hospital

<table>
<thead>
<tr>
<th>BENEFITS - Year One</th>
<th>Dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased Revenue</td>
<td></td>
</tr>
<tr>
<td>Maximize per day bed value by decreasing LOS</td>
<td>$1,310,126</td>
</tr>
<tr>
<td>Decrease non-reimbursable HAI costs</td>
<td>$764,890</td>
</tr>
<tr>
<td>Cost Avoidance</td>
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<tr>
<td>3% CMS penalty for respiratory infections</td>
<td>$899,880</td>
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<td>CMS Quality Index penalty</td>
<td>$899,880</td>
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<tr>
<td>Joint Commission citation</td>
<td>TBD</td>
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<tr>
<td>Employee absenteeism</td>
<td>TBD</td>
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<tr>
<td>HAI litigation by patients</td>
<td>TBD</td>
</tr>
<tr>
<td>Quarterly total</td>
<td>$2,166,803</td>
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<tr>
<td>Cumulative value</td>
<td>$52,166,803</td>
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INVESTMENTS

| Gas | |
| Installation & Integration of New System | $(1,198,500) |
| Maintenance | $(23,850) |
| Operating Cost | $(34,573) |
| OR & PT Room Down Time | $(10,000) |
| Quarterly total | $(1,266,923) |

Total for 1st Quarter: $7,225,018
Cumulative investment: $(1,266,923)

500.97%
Hospitals and insurers see a market advantage with humidification

Payors take note of the value of humidification

1. Leapfrog Quality Report
2. United Healthcare
3. Blue Cross/Blue Shield
4. Veteran Hospital Network

Hospitals looking at humidify for improved patient outcomes

1. Arbors Assisted Living, Vermont has humidified their facility
2. University of Rochester, St. James Hospital
2016 Should ASHRAE consider occupant health in indoor air management?

“[our work] is the design, specification, selection, installation, and operation of HVAC equipment. Research on IAQ and occupant health will suggest complex, esoteric, unproven ‘solutions’ to health issues that will not be helpful and ultimately have little meaning to ASHRAE members.”
ASHRAE is now interested in the health benefits of humidification.

**Indoor parameters affecting health**
- Temperature
- Room air changes
- Room pressurization
- Air-filtration
- **Humidity**
- **Microbiome composition**

**Requiring management of these building elements**
- HVAC system
- Building envelope
- Surface materials
- **Humidifiers**
2019 ASHRAE is now taking a new look at humidification requirements

New ASHRAE publications addressing humidification

• Technical Committee 9.6 Infectious Diseases considers humidification for infection control
• Comfort is replaced by health, Design Manual Guideline, 2020
• ASHRAE Journal Article with Mike Scofield on health, adiabatic cooling and humidification, energy savings

ASHRAE committees looking at IAQ and health:

• Environmental Health Committee
• TC 9.6 Infectious Diseases Subcommittee
• Multi-discipline task Group
• Define *Health*, gaps in ASHRAE mission, changes needed

Nov. 6, 2019 New ASHRAE Tech Hour promoting humidification for health:

• Tech Hour Webcast: Humidification, Occupant Health and Energy Performance
  10,000 viewers internationally
• Anthrax
• Avian influenza
• Varicella disease (chickenpox, shingles)
• Measles (rubeola)
• Severe acute respiratory syndrome (SARS)
• Smallpox (variola)/Varioloa virus
• Tuberculosis (TB)
Redefinition of Airborne Transmission

- Clostridium difficile
- Diphtheria
- Epiglottitis, due to Haemophilus influenzae type b
- Haemophilus influenzae Serotype b (Hib) disease
- Influenza, human (typical seasonal variations)
- Meningitis & Meningococcal disease sepsis, pneumonia
- Mumps (infectious parotitis)/Mumps virus
- Mycoplasmal pneumonia
- Parvovirus B19 infection (erythema infectiosum)
- Pertussis (whooping cough)
- Pharyngitis from Adenovirus, Orthomyxoviridae, Epstein-Barr virus, Herpes simplex virus
- Pneumonia (Adenovirus, Haemophilus influenzae Serotype b, Meningococca Mycoplasma)
- Streptococcus Group A
- Pneumonic plague/Yersinia pestis
- Rubella virus infection (German measles)/Rubella virus
- Severe acute respiratory syndrome (SARS)
- Streptococcal disease (group A streptococcus)
- Viral hemorrhagic fevers due to Lassa, Ebola, Marburg, Crimean-Congo fever viruses
NIH / GSA: Enhancing Health through Indoor Air Quality

Provide Fresh Air

Control Indoor Pollutants

- CFM OA
- PM/VOC/CO2
- T/RH

Manage Humidity
Decrease inflammation, infection, fatigue

National Institute of Health, EPA, AIA, DOH
Change is hard! We resist and often do not even listen!
Do we really want to keep doing the same thing?
Medical professionals
• Heal patients
• Follow clinical protocols
• Avoid lawsuits

Building professionals
• Reduce energy use
• Stay within budget
• Follow building codes

IMPROVE OCCUPANT HEALTH
• Better health
• Decrease acute and chronic diseases
• Decrease financial losses from illness

Uniting our goals would benefit everyone
1. The indoor environment is **critical** for our health.

2. Hydrated indoor air supports occupant health, promotes a diverse microbiome, prevents selection of desiccant-resistant pathogens and optimizes surface cleaning.

3. Humidification can present challenges, but we cannot ignore our need for RH 40%–60%!
Thank you!

Stephanie Taylor, MD, M Arch, FRSPH(UK), M CABE

MD@taylorcx.com
(860) 501-8950
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<th>Pages/DOI</th>
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<td>mSystems 1(2)</td>
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<td>frontiers in</td>
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