40 is the new 20!

Balanced indoor air hydration for health
Presentation summary

A. Why engineers and doctors should talk to each other

B. New data on the impact of buildings on occupant health

C. Dry building syndrome

D. Conclusions and best practices
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Engineers and physicians have much in common

- Many years of school!!!
- Technical vocabulary that excludes outsiders
- Jobs largely controlled by customer budgets
- We both [should] promote human health

“ASHRAE is a global society advancing human well-being through sustainable technology for the built environment”
Who bears the consequences of our poor communication?

Engineers address laws of physics

Clinicians address laws of biology

The occupants!
- allergies
- infections
- discomfort
- absenteeism
“We shape our buildings, then they kill us!”
Chronic diseases are affecting more and more people

- Autoimmune diseases have increased
- Learning disabilities have risen 50% in the past 10 years
- Endocrine disorders such as diabetes have increased 30% since 1985
- Asthma has reached epidemic proportions, now the No. 1 cause of school absenteeism
- Birth defects are the leading cause of infant mortality in the US
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D. Conclusions and best practices
We now have new tools leading to new understanding

Microscope 1509
Telescope 1608
“Gene-o-scope” 2000”
We contain much more than human cells

In 2003 all the DNA from an individual human was sequenced. About 20,000 genes were found—no more than some plants have!

How could such complicated beings as ourselves get by with so few genes?
We are not only humans cells!

Each of us is an ecosystem with ~ one trillion other microscopic organisms living in and on us.
Our microbes relate to the indoor environment

We send our microbes into buildings

Buildings send their microbes into us
Indoor conditions have selected harmful microbes

Many types of microbes outdoor

Few species in buildings
Which building parameters affect occupant health?

Hospitals are a perfect setting to study this question.

Patients are vulnerable.
Pathogens are virulent.
We did a hospital study over one year

Correlate indoor conditions ~ With new patient infections
The hospital building

- Built 2013, LEED Silver
- 1.2 million square feet
- 100,000 square feet per floor
- 240 single-occupancy inpatient rooms
- Green roof
10 patient rooms, 2 nurse stations
Patient room information collected every 30 minutes for 1 year

- Staff & visitor hand cleaning
- Room air changes
- Traffic in & out of room
- RH, absolute humidity
- Outdoor air fractions
- Room pressurization
- Temperature
- Lux
- CO₂ level
### Examples of new patient infections

<table>
<thead>
<tr>
<th>Patient</th>
<th>Room</th>
<th>Clinical symptoms</th>
<th>HAI Organisms (if indicated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>xx</td>
<td>xx</td>
<td>pneumonia, viremia</td>
<td>Pseudomonas, Epstein-Barr virus (EBV)</td>
</tr>
<tr>
<td>xx</td>
<td>xx</td>
<td>pneumonia</td>
<td>Staphylococcus aureus</td>
</tr>
<tr>
<td>xx</td>
<td>xx</td>
<td>open wound of head, neck, and trunk</td>
<td></td>
</tr>
<tr>
<td>xx</td>
<td>xx</td>
<td>bacteremia, organism unspecified</td>
<td>Citrobacter infection</td>
</tr>
<tr>
<td>xx</td>
<td>xx</td>
<td>infection due to vascular device</td>
<td></td>
</tr>
<tr>
<td>xx</td>
<td>xx</td>
<td>cellulitis</td>
<td>Staphylococcus aureus</td>
</tr>
<tr>
<td>xx</td>
<td>xx</td>
<td>sepsis, cellulitis, abscess</td>
<td></td>
</tr>
<tr>
<td>xx</td>
<td>xx</td>
<td>bacteremia, organism unspecified</td>
<td></td>
</tr>
<tr>
<td>xx</td>
<td>xx</td>
<td>pneumonia, organism unspecified</td>
<td></td>
</tr>
<tr>
<td>xx</td>
<td>xx</td>
<td>fever; bacteremia, organism unspecified</td>
<td></td>
</tr>
<tr>
<td>xx</td>
<td>xx</td>
<td>viremia</td>
<td>Cytomegalovirus (CMV)</td>
</tr>
<tr>
<td>xx</td>
<td>xx</td>
<td>wound infection after surgery</td>
<td></td>
</tr>
<tr>
<td>xx</td>
<td>xx</td>
<td>urosepsis, organism unspecified</td>
<td></td>
</tr>
<tr>
<td>xx</td>
<td>xx</td>
<td>sepsis following cardiac surgery</td>
<td></td>
</tr>
<tr>
<td>xx</td>
<td>xx</td>
<td>pneumonia, organism unspecified</td>
<td></td>
</tr>
<tr>
<td>xx</td>
<td>xx</td>
<td>infection of skin and subcutaneous tissue</td>
<td></td>
</tr>
<tr>
<td>xx</td>
<td>xx</td>
<td>colitis and diarrhea</td>
<td>Clostridium difficile</td>
</tr>
<tr>
<td>xx</td>
<td>xx</td>
<td>wound infection after surgery</td>
<td></td>
</tr>
<tr>
<td>xx</td>
<td>xx</td>
<td>urosepsis, organism unspecified</td>
<td>salmonella enteritis</td>
</tr>
</tbody>
</table>
Indoor air RH was found to be the most significant factor associated with patient HAIs.
SPSS analysis of relationships between indoor conditions and infections

<table>
<thead>
<tr>
<th>Model</th>
<th>Standardized Coefficients</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beta</td>
<td>t</td>
<td>Sig.</td>
</tr>
<tr>
<td>1 (Constant)</td>
<td>-2.348</td>
<td>-2.396</td>
<td>.023</td>
</tr>
<tr>
<td>Avg RH</td>
<td>-9.060</td>
<td>-2.396</td>
<td>.020</td>
</tr>
</tbody>
</table>

p< .02
This new data challenges the desire to minimize humidity in occupied spaces.
Presentation summary

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Equilibrium (moving towards entropy) is an irrefutable law of thermodynamics

Dry, thirsty air steals moisture from wherever it can
– a law of physics
Human aging is a battle against dehydration & gravity.

90% dehydration
70% gravity
65% dehydration
60%
We are approximately 80% water

\( \text{H}_2\text{O} \) is essential for:

- Food digestion
- Transport of dissolved \( \text{O}_2 \) and \( \text{CO}_2 \) (breathing)
- Keeping our structure intact
- Our immune system to decrease allergies and infections
We have a vast surface area

Epithelium exposed to air includes:

- skin
- nose, throat, sinuses
- 2,400 kilometers of bronchial tubes
- 500 million “air sacs” in our lungs
Dehydration occurs quickly, causing “Dry building syndrome”

Sitting in room air with 20% RH, the average person becomes clinically dehydrated in 8 hours, *before* thirst sets in.

**Dehydration harms:**

- Brain function & performance
- Skin integrity, wound healing
- Defenses against infections & allergies
Dry building syndrome impairs our brain
Dry building syndrome harms our skin

Skin is essential for:
- wound healing
- immune system training
- protection from injury
- protection from infections
- preserving internal water
Dry air harms our skin

well hydrated

dehydrated
Children and seniors are especially vulnerable to the ill-health effects of low RH

Children

- Delicate fluid balance
- Higher water loss through skin
- No self-control over fluid input
- No control of clothing

Seniors

- Sense of thirst is reduced and thus unreliable in preventing dehydration
- Bedridden people have little autonomy
- Seniors often limit drinking in order to reduce toilet visits
- Bed-ridden people often forget to drink
Dry air makes microbes more infectious

- wider spread
- longer life for many
- re-suspension
- reproduction through more infected hosts
“Moisture content may, indeed, be the most important environmental factor influencing the survival of airborne microbes.”

Dr. Dimmick, Naval Biological Laboratory, Univ. CA, Berkeley, doing research on anthrax spores
Air hydration is essential for our respiratory system

Key functions of respiratory cells:
- Cilia wash particles away from delicate lung tissue
- Mucus layer allows healthy immune modulation to reduce allergic reactions
- Mucous from goblet cells trap pathogens

Dry inhaled air causes:
- Increased susceptibility to infections
- Increased wheezing from allergic disease
Dry building syndrome affects our lungs
Will this cough infect others?
Use this slide if video does not play

Will this cough infect others?
Low indoor RH shrinks aerosolized droplets, promoting greater pathogen spread.

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

**Float time**
- 41 hours
- 1.5 hours
- 6 seconds

**Distance travelled**
- 1m
- 10m+
Indoor air with RH < 40% promotes pathogen transmission in tiny aerosolized droplets.

Droplets carrying bacteria or virus are expelled into the hospital environment and dried rapidly.

Rapid drying of infectious droplets.

Pathogens circulate through the ventilation system.

Recirculate in turbulent flow.

Infectious droplets spread disease to in-patients (HAIs).

Re-contaminate hands and surfaces.
With healthy RH of 40%–60%, infectious droplets settle out of the airborne environment.

Particle behavior with increased air hydration:

- Bedrails and other frequently touched surfaces are more effectively cleaned.
- Hand hygiene is maintained.
- Settled infectious droplets are not re-suspended.
Viability of many viruses is reduced in air with RH 40%–60%

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

High Humidity Leads to Loss of Infectious Virus from Simulated Coughs. U. Illinois, 2013
J Noti, et al.
Dry weather predicts bacterial meningitis outbreaks
Dry weather predicts meningitis outbreaks

- Bacteria spread through the air when the outdoor humidity is low.
- Once the humidity exceeds 40%, the epidemic ends.
Presentation summary

A. Why engineers and doctors should talk to each other
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The great indoor air RH debate!

Protect the building

Protect the occupants

RH: 0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Buildings don’t care about humidity

Facility managers often incorrectly think:

• The drier the air the better
• Easier to dry the air than fix the envelope construction

Occupants need RH between 40% and 60% for optimal health

• Decreased infections
• Fewer allergies
• Improved hydration
• Improved wound healing
• Increased work performance
Sterling diagram published in 1985, with optimal RH level for health of 40%–60%

- Actual humidity in winter season: 45%
- Ideal humidity for winter season: 45%
Some buildings are properly humidified

National Institute of Health animal facility: RH 40%–60%

NASA spacecraft: RH 40%–60%
But most are not!

“Noooooo, just drink water”
builders call it nasty!
They care about water activity!

Fungi don’t care about humidity!

- substrate water
- boundary - surface
- air humidity

declared as water activity
Building insulation quality determines the presence of liquid water needed for mold growth.

<table>
<thead>
<tr>
<th>Good insulation properties</th>
<th>Bad insulation properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>outside  building shell  boundary layer room air</td>
<td>outside  building shell  boundary layer room air</td>
</tr>
<tr>
<td>minus 10 °C</td>
<td>minus 10 °C</td>
</tr>
<tr>
<td>20 °C</td>
<td>6 °C</td>
</tr>
<tr>
<td>22 °C</td>
<td>22 °C</td>
</tr>
</tbody>
</table>

R-value = 2.0 W/m²K

Condensation on the wall starts with a rel. humidity of > 95 %.

R-value = 0.25 W/m²K

Condensation on the wall starts with a rel. humidity of 35 %. With 6 °C the surface temperature of the wall reaches dew point temperature.
Decrease building energy use with proper humidification

- Hospital indoor air change rates (ACH) are kept high because of a mistaken perception that high ACH will yield better IAQ.

- Although counterintuitive, reducing room ACH in hospitals decreases the spread of infectious droplet nuclei.

- Hospitals can save up to 70% HVAC fan and reheat energy costs by reducing ACH by 10%.
Ok, how do we convince customers?

Money speaks!
250 bed hospital’s excess costs due to preventable patient 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>

*2015 volume of a selected 250-bed hospital, APIC calculated costs*
# Projected financial impact of room air humidification for a 250-bed hospital

## Table

<table>
<thead>
<tr>
<th></th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BENEFITS - Year One</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased Revenue</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximize per day bed value by decreasing LOS</td>
<td>$1,310,126</td>
<td>$1,310,126.00</td>
<td>$1,310,126.00</td>
<td>$1,310,126.00</td>
</tr>
<tr>
<td>Decrease non-reimbursable HAI costs</td>
<td>$764,890</td>
<td>$764,890.00</td>
<td>$764,890.00</td>
<td>$764,890.00</td>
</tr>
<tr>
<td>Cost Avoidance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3% CMS penalty for readmissions</td>
<td>$91,787</td>
<td>$91,787.00</td>
<td>$91,787.00</td>
<td>$91,787.00</td>
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<tr>
<td>CMS Quality Index penalty</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Joint Commission citation</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Employee absenteeism</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>HAI litigation by patients</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td><strong>Quarterly total</strong></td>
<td>$2,166,803</td>
<td>$2,166,803</td>
<td>$2,166,803</td>
<td>$2,166,803</td>
</tr>
<tr>
<td><strong>Cumulative value</strong></td>
<td>$2,166,803</td>
<td>$4,333,606</td>
<td>$6,500,409</td>
<td>$8,667,212</td>
</tr>
<tr>
<td><strong>INVESTMENTS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Installation &amp; Integration of New System</td>
<td>$(1,198,500)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Maintenance</td>
<td>$(23,850)</td>
<td>$(23,850)</td>
<td>$(23,850)</td>
<td>$(23,850)</td>
</tr>
<tr>
<td>Operating Cost</td>
<td>$(34,573)</td>
<td>$(34,573)</td>
<td>$(34,573)</td>
<td>$(34,573)</td>
</tr>
<tr>
<td>OR &amp; PT Room Down Time</td>
<td>$(10,000)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Quarterly total</strong></td>
<td>$(1,266,923)</td>
<td>$(58,423)</td>
<td>$(58,423)</td>
<td>$(58,423)</td>
</tr>
<tr>
<td><strong>Cumulative investment</strong></td>
<td>$(1,266,923)</td>
<td>$(1,325,347)</td>
<td>$(1,383,770)</td>
<td>$(1,442,194)</td>
</tr>
<tr>
<td><strong>NET VALUE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cumulative total</td>
<td>$899,880</td>
<td>$3,008,259</td>
<td>$5,116,639</td>
<td>$7,225,018</td>
</tr>
</tbody>
</table>

**1st year net return** $7,225,018
**Breakeven point** 1st Quarter
**ROI (1st year)** 500.97%
How much money could be saved by indoor air hydration in offices?

- Fewer employee sick days
- Increased productivity
- Better student performance
- Cleaner buildings

**Typical business operating costs**

- **1%**
  - Energy costs
- **9%**
  - Rental costs
- **90%**
  - Staff costs in salaries and benefits

**10% Variation**

A 10% variation applied equally to each cost has a far from equal impact.

- **+/- 0.1%**
  - Energy costs
- **+/- 0.9%**
  - Rental costs
- **+/- 9.0%**
  - Staff costs
Conclusions:

- New data correlates low indoor RH with occupant illness and decreased productivity
- Building codes should enforce both minimum and maximum indoor RH levels
- 40 (percent RH) is the new 20!
Docs got us here  YOU must get us out!
Occupants say, please hydrate the air in ....

My hospital room

My school

My office
Thank you!

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

MD@taylorcx.com
(860) 501-8950
What tools would help you?

Please talk to us!!
Extra slides
## Next steps for healthy air-hydration in your building

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
</tr>
</thead>
</table>
| 1    | Record occupant health and productivity data  
     | • Accurately monitor dry building syndrome (DBS) symptoms and illnesses |
| 2    | Monitor indoor air quality in occupied building spaces  
     | • A key starting point is understanding existing indoor RH and how it varies |
| 3    | Identify weaknesses in the building envelope and HVAC systems  
     | • Look for areas which can be improved  
     | • Consult humidification experts |
| 4    | Install and properly maintain appropriate humidification systems  
     | • Energy efficient  
     | • Hygienic |
| 5    | Continue monitoring both indoor air RH and occupant symptoms  
     | • Assess occupant changes after proper indoor air hydration is implemented  
     | • Perform ROI analysis |
Particles in the air that affect our health

<table>
<thead>
<tr>
<th>VOC</th>
<th>Mycotoxin</th>
<th>Allergen</th>
<th>Virus</th>
<th>Mold fragment</th>
<th>Bacteria</th>
<th>Mold spore</th>
<th>Pollen</th>
<th>Mite feces</th>
<th>Mite</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Diameter (um)</th>
<th>0.0001</th>
<th>0.001</th>
<th>0.01</th>
<th>0.1</th>
<th>1</th>
<th>10</th>
<th>100</th>
<th>1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>MERV rating</td>
<td>15</td>
<td>13</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Landing site</th>
<th>blood</th>
<th>alveolus</th>
<th>bronchial tube</th>
<th>sinus</th>
<th>skin</th>
<th>skin contact</th>
<th>Transmission</th>
</tr>
</thead>
<tbody>
<tr>
<td>gaseous</td>
<td>•</td>
<td>•</td>
<td>• particles or droplets (large and small)</td>
<td>•</td>
<td>•</td>
<td>• skin contact</td>
<td>Transmission</td>
</tr>
</tbody>
</table>
Influenza also occurs in dry seasons.