Humans and IAQ

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Today’s Presentation

A problem and an opportunity
- Poor health trends
- The indoor environment is under suspicion

New tools & understanding
- New tools give us new insight
- The microbiome of humans and buildings

The influence of air
- Human physiology and IAQ
- Microbes and IAQ

Optimal indoor air
- Barriers and benefits to change
- Your next steps
This is scary.....

- Patients are dying FROM being in the hospital
- Healthcare costs are prohibitively high
- Chronic disease rates are increasing
- Infectious diseases are re-emerging

What is going on?
We shape our buildings, then they kill us

Is this the problem?
The invisible world

video 1 goes here
New tools give us new understanding

Microscope 1509  
Telescope 1608  
“Gene-o-scope” 2000
Our microbes interact with the building

We send our microbes to buildings

Buildings send their microbes to us
IAQ and the most important outcome

How can we study the impact of the built environment on the most important metric?

What is the most important metric in hospitals?

- energy consumption (or lack of)
- hospital profits
- clinician happiness
- other?
New patient infections guide IAQ management

too many patients

are harmed by **new** infections, “healthcare-associated infections” (HAIs)
A 13 month study on IAQ, bacteria spread & patient infections

- Monitor indoor conditions in 10 patient rooms and 2 nurse stations
- Map bacterial communities in these spaces
- Track patient HAIs

Simon Lax, et.al. U.Chicago, IL 60637
The hospital study site
10 patient rooms, 2 nurse stations
8 million data points from the patient room

- Staff & visitor hand cleaning
- Room air changes
- Traffic in & out of room
- RH, absolute humidity
- Outdoor air fractions
- Room pressurization

- Temperature
- Lux
- CO₂ level

8 million data points!!
Results?
Results: 15% patients got HAIs

<table>
<thead>
<tr>
<th>Patients</th>
<th>Clinical symptoms</th>
<th>HAI Organisms (if indicated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>xx</td>
<td>site of infection not specified</td>
<td>Citrobacter infection</td>
</tr>
<tr>
<td>xx</td>
<td>colitis and diarrhea</td>
<td>Clostridium difficile</td>
</tr>
<tr>
<td>xx</td>
<td>infection due to vascular device</td>
<td>Staphylococcus aureus</td>
</tr>
<tr>
<td>xx</td>
<td>pneumonia, cough</td>
<td>organism unspecified</td>
</tr>
<tr>
<td>xx</td>
<td>urosepsis with catheter</td>
<td>organism unspecified</td>
</tr>
<tr>
<td>xx</td>
<td>post-op Infection of skin and subcutaneous tissue</td>
<td></td>
</tr>
<tr>
<td>xx</td>
<td>bacteremia with central line</td>
<td>organism unspecified</td>
</tr>
<tr>
<td>xx</td>
<td>central line with blood stream infection</td>
<td></td>
</tr>
<tr>
<td>xx</td>
<td>gastritis, enteritis</td>
<td>Cytomegalovirus (CMV), salmonella,</td>
</tr>
<tr>
<td>xx</td>
<td>pneumonia</td>
<td>Pseudomonas</td>
</tr>
<tr>
<td>xx</td>
<td>viral pneumonia</td>
<td>Cytomegalovirus (CMV)</td>
</tr>
<tr>
<td>xx</td>
<td>infection with joint prosthesis</td>
<td>organism unspecified</td>
</tr>
</tbody>
</table>
This new data challenges the desire to minimize humidity in occupied spaces!
Indoor air RH was found to be the biggest driver of patient HAIs.
RH in patient rooms

![Graph showing average daily RH over time for different patient rooms]
SPSS analysis of indoor conditions and infections

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

p < .02
Will this cough infect others?

video 2 goes here
Dry air and humans
People are 75% water

Every bodily function requires H2O

- Food digestion to produce energy and build tissues
- Transport of dissolved $O_2$ and $CO_2$ (breathing)
- Keeping our structure and epithelial layers intact
- Training our immune system to decrease allergies and infections
Our surface area is vast

Epithelium exposed to air includes:

- skin
- nose, throat, sinuses
- 2,400 kilometers of bronchial tubes
- 500 million “air sacs” in our lungs
The universe strives for equilibrium

Dry, thirsty air steals moisture from wherever it can — a law of physics
Dehydration causes “Dry building syndrome”

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

**Dehydration harms:**

- Brain function & performance
- Defenses against infections & allergies
- Skin integrity, wound healing
Even mild dehydration harms our thinking

1% decrease of our body weight from water losses diminishes our:

- ability to think
- short-term memory
- concentration
- reaction times
- visual-motor tracking
Dry air can dehydrate our brain
Dry air harms our respiratory defenses
Inflammatory markers are higher in dry months
Dry air is harmful to 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
Cracks in dry skin allow penetration of inflammatory agents.
Dry air impairs vision

take off  six hours later  landing
Dry air damages our corneas after 30 days at 20% RH.

- **Normal cornea**
- **Dry cornea after 30 days at 20% RH**
Children and seniors are especially vulnerable to the ill-health effects of low RH

**Children**
- Delicate fluid balance
- Higher transdermal water loss
- No self-control over fluid input
- No control on clothing

**Seniors**
- Sense of thirst is reduced and thus unreliable in preventing dehydration
- Bedridden or unconscious persons have no autonomy
- Seniors often limit drinking in order to reduce toilet visits
Unlike humans, pathogens LOVE dry air.
Pathogens can be more infectious in dry air

- Greater transmission through the air
- Prolonged survival in droplet nuclei and spores
- Evasion from surface cleaning through re-suspension
Dry air is great in biological warfare

“Moisture content may 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
Pathogens travel far in dry air

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

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

**Distance travelled:**
- 1m
- 10m+
Infectivity of many viruses is greater in dry air

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 air promotes pathogen transmission in tiny droplets

- Ventilation duct
- Pathogens circulate through the ventilation system
- Recirculate in turbulent flow
- Infectious droplets are expelled into the hospital environment and dry rapidly
- Re-contaminate hands and surfaces
- Infectious droplets spread disease to in-patients (HAIs)
But, with healthy RH of 40%–60%, infectious droplets settle out of the air

Disinfection benefits of proper air hydration:

- Bedrails and other frequently touched surfaces are more effectively cleaned
- Hand hygiene is maintained
- Settled infectious droplets are not re-suspended
Bacteria spread through the air when the outdoor humidity is low

“Once the humidity exceeds 40%, the epidemic ends”

Dry weather reliably predicts meningitis outbreaks
Sterling diagram, 1985, with optimal RH level for health of 40%–60%
Around the world
The great indoor air RH debate!

**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
What gets people’s attention?
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*
ROI humidification & 20% decreased HAIs

<table>
<thead>
<tr>
<th>BENEFITS - Year One</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<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>Quarterly total</td>
<td>$2,166,803</td>
<td>$2,166,803</td>
<td>$2,166,803</td>
<td>$2,166,803</td>
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<tr>
<td>Cumulative value</td>
<td>$2,166,803</td>
<td>$4,333,606</td>
<td>$6,500,409</td>
<td>$8,667,212</td>
</tr>
</tbody>
</table>

INVESTMENTS

<table>
<thead>
<tr>
<th></th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Installation &amp; Integration of New System</td>
<td>$(1,188,500)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>$(23,850)</td>
<td>$(23,850)</td>
<td>$(23,850)</td>
<td>$(23,850)</td>
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<tr>
<td>Operating Cost</td>
<td>$(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>Quarterly total</td>
<td>$(1,266,923)</td>
<td>$(58,423)</td>
<td>$(58,423)</td>
<td>$(58,423)</td>
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<tr>
<td>Cumulative investment</td>
<td>$(1,266,923)</td>
<td>$(1,325,347)</td>
<td>$(1,383,770)</td>
<td>$(1,442,194)</td>
</tr>
</tbody>
</table>

NET VALUE

<table>
<thead>
<tr>
<th></th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<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%
Indoor air hydration ROI in first quarter

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarterly total</td>
<td>$899,880</td>
</tr>
<tr>
<td>Cumulative total</td>
<td>$899,880</td>
</tr>
<tr>
<td>1st year net return</td>
<td>$7,225,018</td>
</tr>
<tr>
<td>Breakeven point</td>
<td>1st Quarter</td>
</tr>
<tr>
<td>ROI (1st year)</td>
<td>500.97%</td>
</tr>
</tbody>
</table>
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.

- Air turbulence plus low RH in clinical spaces contributes to the spread of airborne pathogens as infectious droplet nuclei are propelled further away from an infected human host, exposing other room occupants to infections.

- 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%.
Conclusions: 40 (percent RH) is the new 20!

• New data reinforces the importance of indoor air hydration in patient outcomes

• Dry indoor air harms people

• Collaboration between engineers, building managers and clinicians is key to improving public health
Next steps for healthy indoor air hydration in your building

1. Record patient outcomes and staff absenteeism
   • Work with clinicians to accurately monitor occupant illnesses & absenteeism

2. Monitor relative humidity in occupied building spaces
   • Target **all** important parameters, including harmfully low indoor humidity

3. Identify upgrades needed in the building envelope and HVAC systems

4. Install, run & maintain appropriate HVAC & humidification systems
   • Energy efficient
   • Hygienic

5. Continue monitoring & correlating indoor RH and occupant health
   • Perform ROI analysis
Thank you!

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