L’importance d’humidification envers la santé

Stephanie Taylor, MD, M Arch, RSPH(UK), MCABE
How I got here

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

- Medical doctor since 1984
- Pediatric oncologist at the Dana Farber Cancer Institute, Boston, Massachusetts
- Too many of my patients were dying from being in the hospital
- Masters in Architecture & Engineering
- Started focusing on decreasing infections
- Now studying impact of enclosures on all occupants

Thank you for this opportunity to speak!
We have a problem!

- Allergies, infectious and autoimmune diseases are up
- The indoor environment is under suspicion

New tools give us answers

- The invisible world
- DNA analysis and the microbiome
- HAIs and study

Effects of indoor environments

- Human physiology
- Microbes
- Climate and disease patterns

40 is the new 20!

- Barriers to change
- Benefits to change
- Next steps
What is going on?

- Antibiotic resistance is unstoppable
- Chronic diseases are increasing
- Patients are dying FROM being in the hospital
- Infectious diseases are re-emerging

Most people spend 90% their time indoors

This is confusing.....
The indoor environment is under suspicion - again

Environmental Factors Affecting Health

- **Ventilation and warmth**
  - check the patient’s body temperature, room temperature, ventilation and foul odors

- **Light**
  - check room for adequate light (sunlight is beneficial to the patient)
  - create and implement adequate light in the room without placing the patient in direct sunlight

Florence Nightingale

**MOTHER OF MODERN NURSING**

By: Ezra Viktoria R. Haduca

Environmental Factors Affecting Health

- **Cleanliness**
  - check and keep room from dust, dampness and dirt

- **Health of houses**
  - check surrounding for fresh air, pure water, drainage, cleanliness and light
  - remove garbage and stagnant water

- **Noise**
  - check and attempt to keep noise level in minimum
The Areas of the blue, red, & black wedges are each measured from the centre as the common vertex.

The blue wedges measured from the centre of the circle represent areas for: the deaths from Preventable or Mitigable Zymotic diseases; the red wedges measured from the centre the deaths from wounds; & the black wedges measured from the centre the deaths from all other causes.

The black line across the red triangle in Nov. 1854 marks the boundary of the deaths from all other causes during the month.

In October 1854, & April 1855 the black area coincides with the red; in January & February 1855, the blue coincides with the black.

The entire areas may be compared by following the blue, the red & the black lines enclosing them.
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The invisible world
New tools give us new understanding

Microscope 1509

Telescope 1608

“Gene-o-scope” 2000”
Has anyone ever told you, “You are full of bacteria”?

They are right!

We are more microbial than we are human
Your body is an evolving ecosystem!

- 3-10 times more microbial cells than human cells
- unique for every person
- environmentally acquired each generation
- “microbial signature” evolves
- Microbes influence our
  - genetic diversity
  - normal physiology
  - health state
Our microbes interact with the indoor environment

We send our microbes to buildings

Buildings send their microbes to us
A study to examine buildings and occupant health
Hospitals are dangerous places

More than 10% of patients are harmed by new infections, “healthcare-associated infections” (HAIs)
How bad is this situation?

TITANIC SINKS – 1,500 people drowned

Every SIX days!
We did a hospital study over one year

Correlate indoor conditions with new patient infections
• Built 2013, LEED Silver
• 1.2 million square feet
• 100,000 sq ft per floor
• 240 single-occupancy inpatient rooms
• 52 ICU beds
• 28 ORs
• Levels 8, 9, 10 - surgical, oncology and transplant patient rooms
• Green roof

10 patient rooms, 2 nurse stations
Patient room information collected every 30 minutes for 1 year

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

8 million data points!!
Results?
Indoor air RH was found to be the most significant factor associated with patient HAI.

**Graph**

- **Relative Humidity**
  - 30.00
  - 32.00
  - 34.00
  - 36.00
  - 38.00
  - 40.00
  - 42.00

- **Healthcare-Associated Infections in 10 monitored patient rooms**

- **Avg RH for all patient rooms**

- **Dates**
  - 24-Feb
  - 24-Mar
  - 20-Apr
  - 17-May
  - 13-Jun
  - 10-Jul
  - 6-Aug
  - 2-Sep
  - 29-Sep
  - 26-Oct
  - 22-Nov
  - 19-Dec

**Legend**

- HAI
  - 10
  - 8
  - 6
  - 4
  - 2
RH in patient rooms

Average daily RH
This new data challenges the desire to minimize humidity in occupied spaces!
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>
</tbody>
</table>

$p< .02$
We have a problem!

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Human life is a battle against gravity and dehydration.

- Gravity content:
  - Newborn: 90%
  - Child: 70%
  - Adult: 65%
  - Elderly: 60%

- Visible dehydration:
  - Newborn: 90%
  - Child: 70%
  - Adult: 65%
  - Elderly: 60%
Every bodily function requires water

the average person is 75% H₂O

- Food digestion to produce energy and build tissues
- Transport of dissolved O₂ and CO₂ (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
Dry air is bad for humans
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
Dry air dehydrates our brain
1% decrease of our body weight from water losses diminishes our:

- ability to think
- short-term memory
- concentration
- reaction times
- visual-motor tracking
Dry Building Syndrome affects our respiratory system.
Mucous membranes and inhaled air

50% RH

30% RH

mucus and cilia stopped
How sick we become depends on how deep the “bugs” go.

<table>
<thead>
<tr>
<th>Region</th>
<th>0.1 μm</th>
<th>1.0 μm</th>
<th>10 μm</th>
<th>100 μm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head airway region</td>
<td>2</td>
<td>28</td>
<td>81</td>
<td>50</td>
</tr>
<tr>
<td>Tracheo-bronchiole region</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Alveolar region</td>
<td>14</td>
<td>12</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>
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 building syndrome harms our skin.
Dry air impairs vision

- take off
- six hours later
- landing
Dry air damages eyes

Figure 1.
A. Mean relative humidity (%) and temperature (°C) recordings in the Low humidity room (LH) and vivarium throughout the experiment.

B. Representative H&E staining of corneas cryosections of C57BL/6 mice subjected to low humidity stress for 15 and 30 days (LH15D and 30D, respectively). Note desquamation of apical corneal epithelial cells at LH15D and 30D while control eye (nonstressed, NS) showed normal corneal architecture. Original magnification 10X. Insets indicate high magnification of left area immediately adjacent to inset.

Normal cornea

Dry cornea after 30 days at 20% RH
Dry air increases abnormal blood clotting
Heart attacks and strokes are worse with dehydration.
Children and seniors are especially vulnerable to the ill-health effects of low RH

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

- Sense of thirst is reduced
- Bedridden people have little autonomy
- Seniors often limit drinking in order to reduce toilet visits
Conversely, pathogens love dry air!

- Greater transmission through the air
- Prolonged survival in droplets and spores
- Easier access to deep human tissues
- Evasion from surface cleaning through re-suspension
Dry air is great in biological warfare

“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
Will this cough infect others?
Pathogens travel far in dry air

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

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

**Distance travelled**
- 1m
- 10m+
Ventilation duct
Pathogens circulate through the ventilation system
Recirculate in turbulent flow
Infectious droplets spread disease to in-patients (HAIs)

Infectious droplets are expelled into the hospital environment and dry rapidly

Dry Indoor air promotes pathogen transmission in tiny droplets

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

**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
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.
- 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.
Dry climate and mortality study: 2009

35 year period in 350 counties in US

Panel B: Humidity

Notes: Calculations made using county populations in the year 2000 as weights.
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Sterling diagram, 1985, with optimal RH level for health of 40%–60%

Actual humidity in winter season: Approximately 45%

Ideal humidity for winter season: 40%–60%
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
They care about water activity!

Fungi don’t care about humidity!

Declared as water activity

Boundary - surface

Substrate Water

Air humidity
The quality of building insulation determines the presence of liquid water needed for mold growth – not indoor RH.

### Good Insulation Properties

<table>
<thead>
<tr>
<th>Outside</th>
<th>Building Shell</th>
<th>Boundary Layer</th>
<th>Room Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>minus 10 °C</td>
<td>20 °C</td>
<td>22 °C</td>
<td></td>
</tr>
</tbody>
</table>

**R-value = 2.0 W/m²K**

Identical outside and inside air temperatures, the different results in the inner surface temperature of the wall.

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

### Bad Insulation Properties

<table>
<thead>
<tr>
<th>Outside</th>
<th>Building Shell</th>
<th>Boundary Layer</th>
<th>Room Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>minus 10 °C</td>
<td>6 °C</td>
<td></td>
<td>22 °C</td>
</tr>
</tbody>
</table>

**R-value = 0.25 W/m²K**

Condensation on the wall starts with a rel. humidity of **35 percent**. With 6 °C the surface temperature of the wall reaches dew point temperature.
What gets customer attention?
250 bed hospital’s excess costs due to preventable patient infections

<table>
<thead>
<tr>
<th>Infection Type</th>
<th>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*
### ROI humidification & 20% decreased HAIs in a 250-bed hospital

<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>
</tr>
<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>
</tr>
<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>

<table>
<thead>
<tr>
<th>INVESTMENTS</th>
<th></th>
<th></th>
<th></th>
<th></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>$(1,198,500)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>$(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>Quarterly total</td>
<td>$(1,266,923)</td>
<td>(58,423)</td>
<td>(58,423)</td>
<td>(58,423)</td>
</tr>
<tr>
<td>Cumulative investment</td>
<td>$(1,266,923)</td>
<td>$(1,325,347)</td>
<td>$(1,383,770)</td>
<td>$(1,442,194)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NET VALUE</th>
<th></th>
<th></th>
<th></th>
<th></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 gets huge 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>
Biology never lies: Evolution and RH

skull and nasal cavity of the grassland Saiga antelope
A large cranial air cavity increases ambient RH, preventing dust particles and parasites from entering delicate lung tissue.

the African dessert first cousin
Conclusions: 40 (percent RH) is the new 20!

- New data reinforces the importance of IAQ in occupant health
- Dry Building Syndrome harms people
- Collaboration between engineers, building managers and clinicians is key to improving public health
Next steps for healthy IAQ in your building

1. Record building users’ health and productivity
   • Work with clinicians to accurately monitor occupant illnesses & absenteeism

2. Monitor IAQ 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 IAQ and occupant health
   • Perform ROI analysis
Docs got us here

YOU must get us out!
Thank you!

Stephanie Taylor, MD, MArch, FRSPH(UK), MCABE

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