Special Article

PHYSICAL AND PHYSIOLOGIC PRINCIPLES OF AIR CONDITIONING

PART II

C. P. YAGLOU, M.S.

BOSTON

WINTER AIR CONDITIONING

Humidification.—Artificial humidification, about which so much is heard in connection with winter air conditioning, was shown in the first part of this paper to be relatively unimportant from the standpoint of comfort and, so far as is known, not essential from the standpoint of health.

While a relative humidity of between 40 and 60 per cent would probably be more normal and perhaps more healthful than one between 20 and 30 per cent, it is practically impossible to maintain this high range in cold weather on account of excessive condensation and freezing on the windows and sometimes inside the exposed walls.
Modern building, double glazed windows, well insulated, and adequate ventilation

No condensation problems!

Moisture problems in buildings have in a number of studies been shown to increase the risk for respiratory symptoms. The study Dampness in Buildings and Health (DBH) was initiated with the aim to identify health relevant exposures related to dampness in buildings. A questionnaire study about home environment with a focus on dampness problems and health was conducted in one county of Sweden (8,918 homes, response rate 79%). Building characteristics that were associated with one or more of the dampness indicators were for single-family houses, older houses, flat-roofed houses built in the 1960s and 1970s, houses with a concrete slab on the ground that were built before 1983. Moreover, tenancy and earlier renovation due to mould or moisture problems was strongly associated with dampness. A perception of dry air was associated with window-pane condensation, e.g. humid indoor air.
Indoor air humidity and health – An overview

Peder Wolkoff
D.Sc.(Med) et Ph.D.

What is ”dry air”?

Going to work:
• Good sleep
• No eye and airway irritation symptoms
• Acceptable indoor air quality
• No infection of influenza
• Intact voice
I declare no conflict of interest

Peder Wolkoff
Impact of the humidity indoors

Symptoms
- eyes and airways

Clinical manifestations

Work performance

Perceived
- immediate
- indoor air quality
- comfort

Humidity

Dust mites

Mold

Material degradation
- chemical damage
- moisture damage

Emissions – VOCs

Formaldehyde

Particle dynamics
- deposition - resuspension

Ozone reactivity

Survival +
transmission of
virus/bacteria

Voice productivity

Sleep quality
QoL

Indoor air humidity. Influence on: IAQ, comfort and health

Four + one fundamental issues of concern

1. Indoor air quality: emission-VOCs, deposition/resuspension-particles
2. Perceived air quality: dry/stuffy air/odor: intensity, acceptability, preference
3. Health – symptoms (acute): sensory irritation: eyes and airways
5. Combined effects
Major IAQ complaints past 4 weeks - OFFICAIR study

"Sick building syndrome since 1980s"

"What is dry air" – long-standing

Why indoor air pollutants

Low relative humidity

Air pollutants, VOCs, particles, etc.

Good air quality =

Fanger/Sundell 1993/2000


OFFICAIR study: Detailed results symptoms past 4 weeks

Dry eye causalities?

- **Aggressive chemicals**
  - VOCs/SVOCs
  - Particles (dust)
- **Low humidity**
- **High temperature**
- **Low pressure**
- **Eye diseases (unrecognized/mild)**
Estimated LOAEL and guideline values for sensory irritation in eyes and upper airways from $\text{RD}_{50}$ values*

| VOC                       | $\text{RD}_{50}$ values “mice” | Estimated LOAEL** “mice” | Guideline LOAEL/AF AF = $10 \times 5$
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetaldehyde</td>
<td>5200</td>
<td>346</td>
<td>7</td>
</tr>
<tr>
<td>Butanol</td>
<td>9100</td>
<td>561</td>
<td>11</td>
</tr>
<tr>
<td>2-Ethylhexanol</td>
<td>233</td>
<td>24</td>
<td>0.5</td>
</tr>
<tr>
<td>3-Octanol</td>
<td>1367</td>
<td>110</td>
<td>2</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>757-557</td>
<td>50-66</td>
<td>1-1.3</td>
</tr>
<tr>
<td>Butyl acetate</td>
<td>8333</td>
<td>520</td>
<td>10</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>5</td>
<td>1</td>
<td>0.02</td>
</tr>
<tr>
<td>Hexanal</td>
<td>4200-4633</td>
<td>288-314</td>
<td>~6</td>
</tr>
<tr>
<td>Glutaraldehyde</td>
<td>10.7-56.7</td>
<td>2-7</td>
<td>0.2-1</td>
</tr>
<tr>
<td>Benzaldehyde</td>
<td>48.1</td>
<td>6.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Limonene</td>
<td>6000</td>
<td>392</td>
<td>8</td>
</tr>
<tr>
<td>Toluene</td>
<td>12667</td>
<td>746</td>
<td>15</td>
</tr>
</tbody>
</table>


Humidity and particle resuspension from carpets

Low rel. humidity "increases" deposition of fine particles – for larger particles, resuspension "increases" by increase of rel humidity (some papers)

Particles may be coated with aggravating chemistry
Humidity and intervention in offices by increase of rel humidity

Many intervention studies indicate that increase of rel humidity in offices decrease prevalence of ”SBS” complaints – Compatible with some clinical findings

Many studies show that low humidity (< 30%) is associated with elevated eye symptoms (age dependent)

Derby et al. Sci Technol Built Environ 23 (2016) 30-45
CONCLUSION:
Even with a modest increase in relative humidity locally, the desktop humidifier shows potential to improve tear-film stability and subjective comfort during computer use.
Influencia and humidity – Why a bit more damp may be good for you!

Jane A. Metz, Adam Finn*

In this paper, we have reviewed an emerging hypothesis and some early supporting evidence that low AH is a key causal factor in winter-time influenza peaks in temperate climates. Epidemiological data support this hypothesis as further research into the effects of increasing AH on IVT in humans appears to be warranted. The prospect of reducing influenza-associated morbidity and mortality by increasing the AM in nurseries, classrooms, hospitals, homes for the elderly and general public spaces is an exciting and novel potential strategy for disarming ’flu.

Cold temperature and low rel. humidity has been associated with an increase of ”respiratory tract infections”
Results: The presence of a portable humidifier with an output of 0.16 kg water per hour in the bedroom resulted in an increase in median sleeping hours. AH/RH levels of 11 to 19% compared to periods without a humidifier present. The associated percent decrease in influenza virus survival was 17.5 - 31.6%. Distribution of water vapor through a residence was estimated to yield 3 to 12% increases in AH/RH and 7.8-13.9% reductions in influenza virus survival.

Conclusion: This modeling analysis demonstrates the potential benefit of portable residential humidifiers in reducing the survival of aerosolized influenza virus by controlling humidity indoors.
What is the perception ”dry air”

- Can we perceive dryness, like heat?  **No – no organ**
- Can low humidity cause dry eye symptoms?  **Generally, yes***
- Can low humidity cause dry airways?  **Sometimes*** *(time-dependent)*
- Can VOCs/SVOCs cause dry air?  **Generally, not**
- Can particles (dust) cause dry air?  **Sometimes*** *(depends on surface chemistry and reactivity)*
- Are dry eyes/airways more susceptible to pollutants?  **Yes, possibly** *(in some cases)*
- Can synergistic effects amplify?  **Possibly, yes**

* The perception is or mimicking sensory irritation.
Conclusions

- Increase of humidity increases the emission of polar VOCs
- The emission of unpolar VOCs/SVOCs is not influenced
- Low humidity "increases" the deposition of large particles on surfaces
- Elevated humidity "decreases" the resuspension of large particles
- Low humidity favors survival and transmission for some influenza virus
- Might improve sleep quality (QOL)
- Low humidity does not significantly increase the potency of sensory irritants in the airways - for eyes it is substantially different
- Low humidity or increased water loss from the airways increases the saccharine clearance time and decreases FEV$_1$ in elderly people
- Humidity $<30\%$ RH appears to increase the complaint rate in offices!
- Humidity $>40\%$ RH "may" lower the infectivity of "some" influenza virus!
- Impact of humidity is complex with a number of research gaps!

Impact IAQ

Infectious virus in exhaled breath of symptomatic seasonal influenza cases from a college community

Jing Yan\textsuperscript{a,b}, Michael Grantham\textsuperscript{a,1}, Jovan Pantelic\textsuperscript{a,2}, P. Jacob Bueno de Mesquita\textsuperscript{a}, Barbara Albert\textsuperscript{a}, Fengjie Liu\textsuperscript{a,3}, Sheryl Ehrman\textsuperscript{b,4}, Donald K. Milton\textsuperscript{a,5}, and EMIT Consortium\textsuperscript{6}

Sneezing was rare, and sneezing and coughing were not necessary for infectious aerosol generation. Our observations suggest that influenza infection in the upper and lower airways are compartmentalized and independent.

New routes to consider regarding routes of infection!