Microbiomes of the Built Environment: Homes

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Microbiomes of the Built Environment: From Research to Application
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What is different in homes?

- Prominent effect of outdoor environment on indoor fungi
- Presence of pets
- Sources of humidity: cooking, laundry
- Building materials

How is mold exposure in homes affecting respiratory health?
Lesson learned:
Outdoor environment affects indoor fungi
But not indoor bacteria.
Lesson learned:
- Filtration of supply air reduces outdoor-indoor transport of fungi.
- Occupation affects indoor bacteria more than ventilation system.

Reponen et al., Environ Internat. 1989
Temporal variation
Fungal spores

Lesson learned:
Pets do have an effect on indoor fungal concentration.

## Associations between Diversity versus Home Characteristics
(based on next generation sequencing)

<table>
<thead>
<tr>
<th></th>
<th>Temperature</th>
<th>RH</th>
<th>Age of home</th>
<th>No of occupants</th>
<th>Dog</th>
<th>Cat</th>
<th>Moldiness</th>
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<tbody>
<tr>
<td><strong>BACTERIA</strong></td>
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Kettleson et al. 2014
Cincinnati Childhood Allergy and Air Pollution Study - CCAAPS

- Longitudinal birth cohort study on the role of traffic pollution and bioaerosols in the development of children’s allergy and asthma.
Microbial assessment in CCAAPS

- Qualitative:
  - Water damage
  - Visible mold
  - Moldy odor

- Quantitative
  - Endotoxin (Dust, Inhalable and PM1)
  - B-glucan (Dust, Inhalable and PM1)
  - Total spore count (air)
  - qPCR assay of 36 fungi (dust) – ERMI = Environmental Relative Moldiness Index
  - qPCR assay of Streptomyces (dust)
EXPOSURE AT AGE 1 VS. RECURRENT WHEEZING AT AGE 1

n=574

Lesson learned:
Age 1 wheezing 4 times higher in homes with visible mold.

Iossifova et al., Allergy 62:504-513, 2007
Exposures at age 1 and 7 vs. asthma at age 7 (n=176)

<table>
<thead>
<tr>
<th></th>
<th>Asthma OR (p-value)</th>
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</thead>
<tbody>
<tr>
<td><strong>YEAR 1 EXPOSURE</strong></td>
<td></td>
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<tr>
<td>BetaGlucan (µg/g)</td>
<td>1.17 (0.31)</td>
</tr>
<tr>
<td>Endotoxin (EU/mg)</td>
<td>1.00 (0.99)</td>
</tr>
<tr>
<td>ERMI high vs. low</td>
<td>3.1 (0.04)</td>
</tr>
<tr>
<td><strong>YEAR 7 EXPOSURE</strong></td>
<td></td>
</tr>
<tr>
<td>BetaGlucan (µg/g)</td>
<td>0.79 (0.18)</td>
</tr>
<tr>
<td>Endotoxin (EU/mg)</td>
<td>0.74 (0.13)</td>
</tr>
<tr>
<td>ERMI</td>
<td>0.70 (0.89)</td>
</tr>
<tr>
<td>Visible Mold</td>
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<tr>
<td>Low vs. no</td>
<td>1.04 (0.89)</td>
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<tr>
<td>High vs. no</td>
<td>1.14 (0.81)</td>
</tr>
</tbody>
</table>

ERMI = Environmental Relative Moldiness Index (analysis of 36 fungal species by PCR)

**Lesson learned:**
Timing of mold exposure matters.
Adjusted ORs (95% CIs) for Asthma Diagnosis
Exposure at age 1 versus asthma at age 7

**Age 1 ERMI: Multivariate model**

- ERMI (age 1) *High vs. Low*
- Parent asthma *Yes vs. No*
- Sensitization to HDM *+ vs. -*
- Air conditioning (age 1) *Yes vs. No*

**Adjusted Odd's Ratio (95% confidence intervals)**

- 2.6 (1.1-6.3)

Lessons learned:
- Concentration matters.
- Microbial exposures can also be protective.
Californian birth cohort CHAMACOS: Asthmatic children had lower fungal diversity in their home at age one.

Lesson learned: Microbial diversity matters.

unadjusted Odds Ratio (OR) 4.80, 95% CI is 1.04 to 22.1

Dannemiller et al., Indoor Air (2014)
Size distribution of fungal particles

Particle Concentration (#/cm³)

Aerodynamic Size (μm)

Lesson learned: Particle size matters.

Smaller difference in CFU-count was observed

Seo et al., 2014
Synergistic Effect of Age 1 Traffic Related Particles (TRAP) and Endotoxin at Age 3 wheeze \((n=483)\)

Prevalence of persistent wheeze

| TRAP/  
<table>
<thead>
<tr>
<th>endotoxin</th>
<th>aOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>low/high</td>
<td>0.9 (0.4-1.9)</td>
</tr>
<tr>
<td>low/low</td>
<td>1</td>
</tr>
<tr>
<td>High/high</td>
<td>5.9 (1.9-18.1)</td>
</tr>
<tr>
<td>High/low</td>
<td>1.4 (0.7-3.0)</td>
</tr>
</tbody>
</table>

Adjusted for: tobacco exposure, visible mold, parental asthma, gender, lower respiratory condition, breast feeding.

Lesson learned:
Other, non-microbial exposures matter, too!

Ryan PH et al. Am J Respir Crit Care Med, 2009
Looking into the future

- Mold and dampness problems in buildings may increase due to:
  - Energy efficient tighter houses
  - Increased flooding
Visible mold and water damage index was strongly dose-related to respiratory effects in the first 3 years.

Visible mold categories:

Mendell and Kumagai, 2016 [Epub ahead of print]
Mold exposure vs. Health
Significant associations

Age 1 Mold exposure
- Qualitative
- Quantitative (ERMI)

Age 7 Mold exposure
- Qualitative
- Quantitative (ERMI)

Age 1 Wheeze
Age 3 Wheeze
Age 7 Asthma

Age 7 mold exposure was not associated with age 7 asthma
Association between Steptomyces exposure at age 7 and Exhaled Nitric Oxide (eNO) at age 7 in asthmatic children (n=30)

Parameter estimate = -0.42
p<0.001

Johansson et al. Environ. Internat., 2013
CCAAPS: Exposure at age 7 vs. health at age 7
n=176

<table>
<thead>
<tr>
<th>YEAR 7 EXPOSURE</th>
<th>Any Asthma OR (p-value)</th>
<th>Exhaled NO Parameter estimate (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DUST</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BetaGlucan (µg/g)</td>
<td>0.79 (0.18)</td>
<td>0.01 (0.85)</td>
</tr>
<tr>
<td>Endotoxin (EU/mg)</td>
<td>0.74 (0.13)</td>
<td>-0.02 (0.75)</td>
</tr>
<tr>
<td>ERMI</td>
<td>1.00 (0.89)</td>
<td>&lt;0.01 (0.84)</td>
</tr>
<tr>
<td><strong>VISUAL OBSERVATION</strong></td>
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<tr>
<td>Visible Mold (1 vs 0)</td>
<td>0.79 (0.63)</td>
<td>0.31 (0.42)</td>
</tr>
<tr>
<td>Visible Mold (2 vs 0) df=2</td>
<td>1.14 (0.81)</td>
<td>0.15 (0.26)</td>
</tr>
<tr>
<td><strong>AIR</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BetaGlucan (ng/m³)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inhalable</td>
<td>0.72 (0.01)</td>
<td>-0.03 (0.58)</td>
</tr>
<tr>
<td>PM1</td>
<td>1.07 (0.45)</td>
<td>-0.04 (0.55)</td>
</tr>
<tr>
<td>Endotoxin (EU/m³)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inhalable</td>
<td>0.80 (0.05)</td>
<td>-0.04 (0.35)</td>
</tr>
<tr>
<td>PM1</td>
<td>0.85 (0.32)</td>
<td>-0.14 (&lt;0.01)</td>
</tr>
<tr>
<td>Spore Count #/m³</td>
<td>0.80 (0.15)</td>
<td>0.03 (0.55)</td>
</tr>
</tbody>
</table>

Year7: significant associations were seen only with air results
FURTHER ASSESSMENT OF ERMI (n=289)

Three species were found to be most significantly associated with asthma:

- *Aspergillus ochraceus*
- *Aspergillus unguis*
- *Penicillium variabile*

Reponen et al., JACI 2012