Climate and housing factors that affect indoor allergens, mold, and asthma

Ginger L. Chew, ScD
EPA commissioned a report from the Institute of Medicine (IOM) that:

• summarizes the state of scientific understanding of the effects of climate change on indoor air quality and public health.

*Published in 2011  http://www.nap.edu/catalog.php?record_id=13115
Committee on the Effect of Climate Change on Indoor Air Quality and Public Health

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  Chair
  Harvard School of Public Health

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  Colorado School of Public Health

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  London School of Hygiene and Tropical Medicine

- Steven M. Holland, M.D.
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- Vivian E. Loftness, M.Arch., F.A.I.A
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- Linda A. McCauley, Ph.D., F.A.A.N., R.N.
  Emory University

- William W. Nazaroff, Ph.D.
  University of California, Berkeley

- Eileen Storey, M.D., M.P.H.
  Division of Respiratory Disease Studies, NIOSH
World Map of the Prevalence of Clinical Asthma

Proportion of population (%)*

- **≥10.1**
- **7.6-10.0**
- **5.1-7.5**
- **2.5-5.0**
- **0-2.5**
- **No standardised data available**

Masoli et al., Global Initiative for Asthma (GINA) publication, 2004
## Summary of Findings from the National Academy of Sciences (NAS)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Asthma Development</th>
<th>Asthma Exacerbation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Biological agents</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dust mite allergen</td>
<td>✓+</td>
<td>✓+</td>
</tr>
<tr>
<td>Cockroach allergen</td>
<td>✓-</td>
<td>✓+</td>
</tr>
<tr>
<td>Fungi</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>Rodent allergen</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Chemical agents</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ETS (in preschool-aged children)</td>
<td>✓</td>
<td>✓+</td>
</tr>
<tr>
<td>NO2</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>ETS (in school-aged and older children)</td>
<td>-</td>
<td>✓-</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>-</td>
<td>✓-</td>
</tr>
<tr>
<td>Pesticides</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Plasticizers</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>VOCs</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

- ✓+ = sufficient evidence of a causal relationship
- ✓ = sufficient evidence of an association
- ✓- = limited or suggestive evidence of an association
- - = inadequate or insufficient evidence to determine whether or not an association exists

*NAS, Institute of Medicine. Clearing the Air. 2000*
# Newer findings

<table>
<thead>
<tr>
<th>Factor</th>
<th>Asthma/ allergy references</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Biological agents</strong></td>
<td></td>
</tr>
<tr>
<td>Fungi</td>
<td>Jaakola et al., 2005</td>
</tr>
<tr>
<td>Rodent allergen</td>
<td>Matsui et al., 2006</td>
</tr>
<tr>
<td><strong>Chemical agents</strong></td>
<td></td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>Mendell, 2007</td>
</tr>
<tr>
<td>Pesticides</td>
<td>Salam et al., 2004</td>
</tr>
<tr>
<td>Plasticizers</td>
<td>Bornehag et al., 2004, Jaakola et al., 2008</td>
</tr>
<tr>
<td>VOCs</td>
<td>Rumchev et al., 2004</td>
</tr>
<tr>
<td>(secondary chemical reactions)</td>
<td>Weschler, 2009</td>
</tr>
<tr>
<td>Antimicrobial agents</td>
<td>Clayton et al., 2012, Savage et al., 2012</td>
</tr>
<tr>
<td>(e.g., Triclosan)</td>
<td></td>
</tr>
</tbody>
</table>
Percentage of Children Aged <18 Years with Selected Allergies, by White, Black, or Asian Race (National Health Interview Survey), United States, 2008

MMWR (October 16, 2009)/ 58(40); 1127
Among general population, where are indoor allergens in the hierarchy?

*SALO ET AL., J. ALLERGY CLIN. IMMUNOL, 2011

*NHANES 2005-6 IgE data
### Allergy Prevalence - NHANES 1998-1994

Skin prick Test data (Children ages 6-16)

**Table I. Sample characteristics and prevalence of allergen sensitivity**

<table>
<thead>
<tr>
<th></th>
<th>Sample (n)</th>
<th>Weighted (%)</th>
<th>Any allergen</th>
<th>Cockroach</th>
<th>Dust mite</th>
<th>Cat</th>
<th>A alternata</th>
</tr>
</thead>
<tbody>
<tr>
<td>All children</td>
<td>4164</td>
<td>100.0</td>
<td>43</td>
<td>20</td>
<td>25</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>2057</td>
<td>52</td>
<td>48</td>
<td>22</td>
<td>29</td>
<td>17</td>
<td>19</td>
</tr>
<tr>
<td>Female</td>
<td>2107</td>
<td>48</td>
<td>37</td>
<td>18</td>
<td>21</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td><strong>Age (y)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-11</td>
<td>2520</td>
<td>53</td>
<td>38</td>
<td>17</td>
<td>22</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>12-16</td>
<td>1644</td>
<td>47</td>
<td>48</td>
<td>22</td>
<td>29</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td><strong>Race-ethnicity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White NH</td>
<td>1116</td>
<td>73</td>
<td>41</td>
<td>16</td>
<td>24</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>Black NH</td>
<td>1502</td>
<td>17</td>
<td>52</td>
<td>33</td>
<td>29</td>
<td>15</td>
<td>22</td>
</tr>
<tr>
<td>Mexican American</td>
<td>1546</td>
<td>10</td>
<td>43</td>
<td>25</td>
<td>24</td>
<td>12</td>
<td>14</td>
</tr>
</tbody>
</table>

African American: OR = 2.5 [1.9-3.2]
Mexican American: OR = 1.9 [1.3-2.8]
White: reference category

Dust mite sensitization and wheeze (Multi-site German study)

Figure 1: Proportion of wheezing in children with and without sensitisation to mite allergen, by age

*p < 0.001.

Lau et al., Lancet 2000
Cockroach exposure associated with cockroach allergy
New York preschool children (n=341)

Bla g 2 levels >1U/g in children’s bed and kitchen dust samples were independently associated with cockroach-specific IgE, adjusting for other covariates (such as asthma)

Chew, Perzanowski, Canfield et al, JACI 2008
Sensitization & Exposure to Cockroach allergen: Risk for Emergency Visits in the Inner Cities

# 1 = SPT-/ Bla g 1 ≤ 8 U/g
# 2 = SPT-/ Bla g 1 > 8 U/g
# 3 = SPT+/ Bla g 1 ≤ 8 U/g
# 4 = SPT+/ Bla g 1 >8 U/g

Common indoor allergens

- Dust mite (Der f 1)
- Cockroach (Bla g 1 & 2)
- Mouse (Mus m 1)
Sources vs. Relevant Agent

- Dust mite size (200 microns) vs. Particle size (10-40 microns)
- Particle size vs. Allergen size (25kD)
- Location of organism vs. Location of allergen-laden particles

Dust mite

Fecal pellet

Allergens
Dust mite distribution
Are dust mites ubiquitous?

Clinical Experimental Allergy, 1992, Volume 22, pages 589–590

FM Kneist and JEMH van Bronswijk

Correspondence

House dust mite avoidance—the right way to go forward

Sirs. Allergy to house dust mite is a world-wide problem, compounded by more or less tightly closed houses with fitted carpets and soft furnishings which provide the ideal habitat for the house dust mite.

TABLE I. Prevalence of specific species of dust mites in 252 homes surveyed in eight locations

<table>
<thead>
<tr>
<th>Location</th>
<th>No. mite positive homes</th>
<th>DF No.</th>
<th>DF %</th>
<th>DP No.</th>
<th>DP %</th>
<th>EM No.</th>
<th>EM %</th>
<th>BT No.</th>
<th>BT %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cincinnati, Ohio</td>
<td>48</td>
<td>46</td>
<td>95.8</td>
<td>39</td>
<td>81.3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>New Orleans, La.</td>
<td>58</td>
<td>47</td>
<td>81.0</td>
<td>57</td>
<td>98.3</td>
<td>18</td>
<td>31.0</td>
<td>3</td>
<td>5.2</td>
</tr>
<tr>
<td>Memphis, Tenn.</td>
<td>31*</td>
<td>29</td>
<td>93.5</td>
<td>24</td>
<td>77.4</td>
<td>4</td>
<td>12.9</td>
<td>1</td>
<td>3.2</td>
</tr>
<tr>
<td>Galveston, Texas</td>
<td>32</td>
<td>30</td>
<td>93.8</td>
<td>31</td>
<td>96.9</td>
<td>14</td>
<td>43.8</td>
<td>6</td>
<td>18.8</td>
</tr>
<tr>
<td>Greenville, N.C.</td>
<td>36</td>
<td>36</td>
<td>100.0</td>
<td>34</td>
<td>94.4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Delray Beach, Fla.</td>
<td>8</td>
<td>8</td>
<td>100.0</td>
<td>6</td>
<td>75.0</td>
<td>1</td>
<td>12.5</td>
<td>2</td>
<td>25.0</td>
</tr>
<tr>
<td>San Diego, Calif.</td>
<td>25*</td>
<td>21</td>
<td>84.0</td>
<td>25</td>
<td>100.0</td>
<td>2</td>
<td>8.0</td>
<td>11</td>
<td>44.0</td>
</tr>
<tr>
<td>Los Angeles, Calif.</td>
<td>13</td>
<td>12</td>
<td>92.3</td>
<td>12</td>
<td>92.3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>251*</td>
<td>229</td>
<td>91.2</td>
<td>228</td>
<td>90.8</td>
<td>39</td>
<td>15.5</td>
<td>23</td>
<td>9.2</td>
</tr>
</tbody>
</table>

*All 32 homes tested contained mites, but species could not be determined in one house because of lack of enough adult specimens, therefore 252 homes were mite positive.
Are dust mites important when allergen levels are low?

TABLE I. Prevalence of IgE antibody to indoor allergens among middle-school children

<table>
<thead>
<tr>
<th>Allergen</th>
<th>Subjects with symptoms</th>
<th>Control subjects (n = 54)</th>
<th>p Value†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BHR⁺ (n = 21)</td>
<td>BHR⁻ (n = 36)</td>
<td></td>
</tr>
<tr>
<td>Dust mite</td>
<td>1 (5)</td>
<td>6 (17)</td>
<td>2 (4)</td>
</tr>
<tr>
<td>Dog</td>
<td>14 (67)</td>
<td>7 (19)</td>
<td>8 (15)</td>
</tr>
<tr>
<td>Cat</td>
<td>13 (62)</td>
<td>10 (28)</td>
<td>9 (17)</td>
</tr>
<tr>
<td>Cockroach</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Russian thistle</td>
<td>10 (48)</td>
<td>10 (28)</td>
<td>12 (22)</td>
</tr>
<tr>
<td>Ryegrass</td>
<td>6 (29)</td>
<td>9 (25)</td>
<td>22 (41)</td>
</tr>
</tbody>
</table>

*Prevalence of at least 40 RU or CAP of at least grade II.
†Significance assessed by chi-square test for trends.
Mite sensitization among Latina women in New York, where dust-mite allergen levels are typically low

Abstract In New York (NY), Latinos often have greater asthma morbidity than other ethnicities, and dust-mite sensitization is common despite low allergen levels. We investigated mite allergen exposure and sensitization in atopic and/or asthmatic women, the majority being Puerto Rican. Women (n = 274) recruited for a birth cohort study were visited postnatally. Dust from their homes was analyzed for mite allergens (Der f 1, Der p 1, and Blo t 5). Serum was analyzed for total and allergen-specific IgE. Thirty-seven percent were sensitized to Dermatophagoides pteronyssinus, 34% to Dermatophagoides farinae, and 21% to Blomia tropicalis. Only 5% of NY homes had levels of Der f 1 > 2 μg/g; none had Blo t 5 or Der p 1 above this level. Caribbean or Latin American birthplace (a proxy for childhood exposure) was not associated with mite sensitization. Sensitization to D. pteronyssinus and D. farinae was associated with a report of doctor-diagnosed asthma [Odds ratio (OR) = 3.27, P = 0.003; OR = 2.81, P = 0.010, respectively]; sensitization to any mite was associated with asthma medication use in the past 12 months (OR = 3.12, P = 0.004). These associations held even after adjustment for cockroach, mouse, and cat sensitization.
Dust mite allergen is associated with increased probability of dust mite sensitization and asthma.

Odds ratio [95% confidence interval] = 2.55 [1.3 - 5.1]

JACI, 128: 284-92, 2011
Increased Heating and Air Conditioning

Institute of Medicine (IOM) 2011

Jacobs, Wilson, Dixon, Smith, and Evens. EHP, 2009
In 2007, only 11 percent of households in Brazil and 2 percent in India had air-conditioning, compared with 87 percent in the United States, which has a more temperate climate, said Michael Sivak, a research professor in energy at the University of Michigan.

“There is huge latent demand,” Mr. Sivak said. “Current energy demand does not yet reflect what will happen when these countries have more money and more people can afford air-conditioning.”
The Green Housing Study

Sample of scheduled renovations
The Green Housing Study Team

**CDC**
(PI) Ginger Chew
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Mary Jean Brown
Sandra Chaves, Marika Iwane
Ben Blount, Antonia Calafat, Rey DeCastro
Udeni Alwis, Connie Sosnoff,
Charles Dodson, Curtis Blanton
Fuyuen Yip, Shahed Iqbal, Kanta Sircar
Behrooz Behbod
Ju-Hyeong Park

**HUD**
Peter Ashley

**EPA**
Dan Stout
Karen Bradham
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Jonathan Levy, Patricia Fabian, Megan Sandel,
Johnna Murphy

**Arizona State University**
Nongjian Tao, Francis Tsow, Erica Forzani
Green Criteria

- Optimized heating, ventilation and air conditioning (HVAC) system
- Recycled building materials
- Energy efficient appliances
- Low/no volatile organic compound (VOC) Carpets and paint
- Integrated Pest Management
- Improved Insulation
Integrated Pest Management (IPM)

Physical Changes
- Kitchen and Bathroom
  - Cleaning
  - Pesticide application (low toxicity)
  - Sealing cracks and holes
- Child’s Bedroom
  - Cleaning
  - Pesticide (low toxicity)

Education
- Clean up spills
- Eat only in kitchen
- Use sealed food containers
- Dispose of trash frequently

* Cleaning to remove dead cockroaches and fecal pellets that could contain allergen
Asthma

**Strategies**
- IPM
- Low VOC Materials
- Insulation
- Ventilation

**Outcomes**
- ↓ pests
- ↓ indoor chemicals*
- ↓ mold growth
- ↓ respiratory inflammation
- ↓ Asthma Morbidity

* Indoor chemicals including VOCs and pesticides
Objective:
To quantify levels of mold, allergens, pesticides, particulates, and volatile organic compounds (VOCs) in Green and control housing.

Study Design:
Repeated measures (started in Fall 2011)

Boston
n = 51 apartments

Cincinnati
n = 51 apartments
Rehabilitation begins

Collect data (pre-rehabilitation)

Collect data (in rehabilitated home)

Collect data (in rehabilitated home)

Collect data (in rehabilitated home)

Time (months)

-1

0

6

12

Control #1

or

Control #2
Environmental Sampling

- **Allergens and Fungi**
  - Vacuum dust sampling

- **Pesticides**
  - Wipe samples from kitchen floor

- **VOCs**
  - Passive air diffusion badges
Environmental Sampling (cont’d)

Novel Air Sampling

- Real-time exposure levels displayed and stored in the cell phone
- Wearable/pocket size
- Sensitive (ppb – ppm)
- Multiple analytes testing
- Selective (immune to common interferents)
- Real-time (sec. to min.)
- Low-cost (< a few hundred $)
- User-friendly / No expertise
- Robust for field testing

Traditional Air Sampling

Chemical badges
## Clinical Measurements

<table>
<thead>
<tr>
<th>Factor</th>
<th>Child with asthma (Age 7-12)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Blood</strong></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>✔</td>
</tr>
<tr>
<td><strong>Urine</strong></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>✔</td>
</tr>
<tr>
<td>Baseline (part 2)</td>
<td>✔</td>
</tr>
<tr>
<td>6-mo. follow-up</td>
<td>✔</td>
</tr>
<tr>
<td>12-mo. follow-up</td>
<td>✔</td>
</tr>
<tr>
<td><strong>Pulmonary Function Test</strong></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>✔</td>
</tr>
<tr>
<td>Baseline (part 2)</td>
<td>✔</td>
</tr>
<tr>
<td>6-mo. follow-up</td>
<td>✔</td>
</tr>
<tr>
<td>12-mo. follow-up</td>
<td>✔</td>
</tr>
<tr>
<td><strong>Exhaled Nitric Oxide</strong></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>✔</td>
</tr>
<tr>
<td>Baseline (part 2)</td>
<td>✔</td>
</tr>
<tr>
<td>6-mo. follow-up</td>
<td>✔</td>
</tr>
<tr>
<td>12-mo. follow-up</td>
<td>✔</td>
</tr>
<tr>
<td>Factor</td>
<td>Child with asthma (Age 7-12)</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td><strong>Respiratory Symptoms</strong></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>✓</td>
</tr>
<tr>
<td>Baseline (part 2)</td>
<td>✓</td>
</tr>
<tr>
<td>3-mo. follow-up</td>
<td>✓</td>
</tr>
<tr>
<td>6-mo. follow-up</td>
<td>✓</td>
</tr>
<tr>
<td>9-mo. follow-up</td>
<td>✓</td>
</tr>
<tr>
<td>12-mo. follow-up</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Flu /cold nasal swabs</strong></td>
<td></td>
</tr>
<tr>
<td>As needed</td>
<td>✓, ?</td>
</tr>
<tr>
<td></td>
<td>✓, ?</td>
</tr>
<tr>
<td></td>
<td>✓, ?</td>
</tr>
<tr>
<td></td>
<td>✓, ?</td>
</tr>
<tr>
<td><strong>Text messaging for cold/flu symptoms</strong></td>
<td></td>
</tr>
<tr>
<td>Months 1, 2, 4, 5, 7, 8, 10, 11</td>
<td>✓</td>
</tr>
</tbody>
</table>
Improved Exposure Assessment

- Air exchange rates
- Time/activity patterns
- Geographic Information Systems

Spatial relationships between residential locations and EPA monitoring sites for PM2.5 and PM10. Liao et al., EHP, 2006
Preliminary Results (2011-2012)

Boston
n = 51 apartments

Cincinnati
n = 51 apartments
Green vs. Control homes in Cincinnati
(n=18 pairs of apartments)

No significant difference in temperature; however,

Relative Humidity
Control (37 %) vs. Green (43 %), p =0.03
Questions about variables that could affect dust mites

During the winter, do you add moisture to the air in your home?

Yes    No

During the winter, how comfortable is the temperature in your home?

- About right
- Too hot
- Too cold
Green vs. Control homes in Boston
(examples of real-time data)

December (Control home)

“Yes, it is too hot in my home during winter.”
Green vs. Control homes in Boston (Real-time Relative Humidity data)

Early Spring (Control home)

Early Spring (Green home)

Do you add moisture to your home during winter?
Is this déjà vu?

Climate Zone Map of United States

* from ASHRAE 90.1-2010 and Briggs RS, ZT Taylor, and RG Lucas. 2003. “Climate Classification for Building Energy Codes and Standards.”
Green Housing Study: Pilot data from Atlanta

- Concentration displayed on log scale.
- Error bars represent 1 unit increase in geometric standard deviation.
Will this also lead to a decrease in mold growth?

Probably not, because...
"...about 75% of households with incomes above $100,000 use central air conditioning compared to just 44% of households below the poverty line."
What about the other indoor allergens?

Shifts in species?
Similar to those of dust mites
IPM intervention:
Inner-City Asthma Study (ICAS)

Significant decrease in Bla g 1 from baseline to 2-year follow-up, and....

Cost = $750-$1000 per child per year

Morgan et al., NEJM (2004)
Multicomponent intervention

Community health workers:

- reduced asthma symptom days
- reduced urgent health services
- Improved caregiver quality-of-life score

Multi-faceted interventions

Effectiveness of home-based, multi-trigger, multicomponent interventions with an environmental focus for reducing asthma morbidity

Housing interventions and control of asthma-related indoor biologic agents: a review of the evidence.
The Future of Interventions
(Better/safer building materials and practices)

Is it enough to remove just 4 feet of drywall?
The Future of Interventions
(more resilient homes)

Before

After
The Future of Interventions
(Green/Smart Homes)

Takaro et al., Am. J. Public Health, 2011
Thank you

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The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.