

# **An Asthma Intervention Pilot Study in Public Housing: Lessons and Baseline Data**

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## **ABSTRACT**

Nine families with asthmatic children living in a public housing development in Boston were enrolled in an asthma intervention program aimed at reducing environmental factors associated with their housing. Interventions were tailored to each residence. Given the small sample size, the purpose of the study was two-fold: first, to document lessons that would make future studies and programs directed at childhood asthma among public housing residents more successful; and second, to collect a high density of environmental measurements of biological and chemical contaminants and physical factors in order to generate hypotheses about possible asthma intervention programs for public housing. Reported here are baseline data and lessons learned about conducting asthma research in public housing. Visual observation suggested that overheating, cockroaches, moisture problems, mice, and overcrowding were common. Used upholstered furniture and multiple mattresses both in the child's room and slept in by the child were found. Quantitative assessment shows high temperature, very low relative humidity in February, high levels of cockroach antigen, relatively moderate levels of other antigens, variable levels of viable fungal spores, and elevated nitrogen dioxide levels. We conclude that the levels of environmental contaminants were largely similar to other reports of asthmatic inner-city children. Further, despite formidable difficulties working with this low socio-economic status, inner-city population, we succeeded in gaining active support for the project by forming a partnership with a community-based organization and by building positive relationships between the field team and the residents.

## **INTRODUCTION**

### **Asthma demographics**

Asthma is one of the most important chronic illnesses in the United States today. According to the Centers for Disease Control and Prevention (CDC), the self-reported prevalence of asthma increased by 75% from 1980 to 1994. The largest increases were among children 0-14 years of age. From 1975 to the years 1993-1995, office visits for asthma doubled. Hospitalization and emergency room visit rates were higher among Blacks than among Whites. Mortality from asthma, which had decreased from the years 1960-1962 to the years 1975-1977, has risen steadily since. During the years 1993-1994 there were an estimated 13.7 million persons with asthma in the U.S. By the years 1993-1994, asthma rates



were higher in the Northeastern U.S. than in other regions.<sup>1</sup> Costs associated with asthma of almost \$2 billion annually have been reported.<sup>2</sup> Asthma tops the list of diseases targeted for disease management by managed care organizations because of high cost, prevalence, and the potential to address the disease through therapy and modification of environmental factors.<sup>3,4</sup>

The increase in asthma has been most marked in children and in minority populations, and there is mounting evidence that inner-city and urban populations are most at risk.<sup>1, 5-10</sup> One study that compared across racial categories found that ever having asthma was reported by 6.4% of Whites, 9.1% of Blacks, 4.5% of Mexican-Americans, 8.8% of Cuban-Americans, and 20.1% of Puerto Rican-Americans.<sup>11</sup> High rates of asthma have been reported in schools with mostly Black or low socio-economic status students in Chicago (about 20% ever having asthma and about 39% ever having wheeze).<sup>6</sup>

## **Environmental factors**

The candidates for key factors affecting asthma morbidity and mortality can be broken down into treatment-oriented factors (e.g., medication) and environmental factors (e.g., housing conditions and air pollution). Many environmental factors are associated with exacerbating or causing asthma.<sup>12</sup> In urban centers, the role of ambient air pollution as a risk factor, particularly ozone, nitrogen dioxide (NO<sub>2</sub>), sulfur dioxide, and particulate matter, has been widely investigated.<sup>13-15</sup> Studies suggest that exhaust fumes from motor vehicle traffic may exacerbate asthma in children.<sup>16</sup> The role of ambient air pollution in causing increases in asthma is in question, however, since such pollutants have declined over the same period that asthma has increased.<sup>1,17</sup>

Recently, attention has shifted to the role of indoor environmental risk factors, especially in the home, schools and, in the case of occupational asthma, the workplace. Well documented risk factors in the home include moisture and mold growth, pest infestation, high dust levels, improper heating, inadequate ventilation, and exposure to secondhand cigarette smoke.<sup>18-27</sup> All of these factors are likely to increase with lower socio-economic status and/or with deteriorating housing conditions.

## **Intervention studies**

Attempts to show that broad, population-based intervention can reduce asthma severity are in their early stages and have met with limited success thus far. Early attempts to see effects from intervention relied largely on educational efforts that were reported to have little or no impact.<sup>28-32</sup> To the extent that these studies could show reductions in morbidity from asthma, they mainly showed reductions in emergency room use among more severe asthmatics.<sup>32</sup>

A case control study compared asthmatics who had been hospitalized with those who had not.<sup>33</sup> Hospitalized cases were less likely to have an asthma management plan, or to report washing bed sheets in hot water for dust mite control. A clinic-based intervention observed that training for clinic staff led to better use of medication by patients and more education of patients.<sup>34</sup> Cowie et al.<sup>35</sup> reported that providing a peak flow meter as part of an asthma management plan that emphasized proper use of medication led to significantly reduced emergency room visits. Another study suggests that enrollment of asthmatic patients in an "Asthma Nurse Practice" program that provided education and adjustment of medication doses reduced asthma symptoms.<sup>36</sup>

The National Cooperative Inner-City Asthma Study has reported intervention results that are particularly relevant to this study. Evans et al. applied an intervention in a randomized clinical trial.<sup>37</sup> They had masters-level social workers administer the intervention, which included providing information to the



physician of enrolled participants, education of the participants based on the A+ Program<sup>38</sup>, referral to smoking cessation programs, and provision of pillow and mattress covers. Over 1 year, the intervention group (n=515) reported about half a day less of symptoms than did the controls (n=518) which was statistically significant (p=0.004). Among children with more severe asthma, there was a larger improvement (1½ symptom days). A second Inner-City Asthma Study report described attempts, largely unsuccessful, to reduce cockroach antigen by use of pesticide extermination.<sup>39</sup>

## **Public housing**

The residents of Boston public housing have a median income that is 17% of the Boston rate. The Franklin Hill Housing Development, in which we conducted this study, was 43% Black, 55% Hispanic, 1% White, and 2% Asian, and 54% were under the age of 18.<sup>40</sup> Because they are at the lowest end of the socio-economic scale and consist largely of minorities, public housing residents may be at risk for exposure to many factors associated with housing that can affect health.<sup>12,41-47</sup> Previous community-based research found high rates of both poor housing conditions and asthma in this and another Boston public housing development.<sup>48</sup> These studies documented widespread overheating in winter, alternating with use of gas ovens for heating during transitional weather. Moisture and water damage, mold growth, lack of fresh air, pest infestation, damage to walls and ceilings, and high smoking rates were reported.

## **METHODS**

### **Recruitment**

A single housing development, the Franklin Hill Housing Development in the Dorchester neighborhood of Boston, Massachusetts, was studied. The development was built in the 1940s and has not undergone major renovations since it was built (renovations reported herein, therefore, refer to modest construction that is closer to patching and repairing than to gut rehabilitation). The development has 364 apartments, most of which are occupied, that are in 9 buildings situated close to each other and house about 980 residents. It has no mechanical source of ventilation other than fans in some bathrooms. Apartments have windows on one or at most two sides. Heating is by steam carried to radiators through piping that runs indoors along interior walls and is not insulated. Nine families were recruited by the outreach staff of the Committee for Boston Public Housing and by residents enrolled in their Action Against Asthma Health Advocate Training Certificate Program. The protocol for the study was approved independently by each Institutional Review Board affiliated with the Tufts University School of Medicine, the Harvard University School of Public Health, and the Boston Medical Center.

Families had to meet the following criteria:

1. At least one child aged 3-17 years old with physician-diagnosed asthma.
2. The child must live in the apartment at least 5 days per week.
3. Willingness and ability to stay in the study for 6 months.
4. Willingness and ability to allow researchers access to the apartment 1-2 times per month.
5. Verbal commitment to follow the asthma protocol as assigned, including keeping asthma diaries.
6. One or more risk factors for asthma in the apartment.
7. Verbal commitment to prohibit smoking in the apartment during the study.

### **Diagnosis**



The index asthmatic children underwent a clinical evaluation performed by a pediatric pulmonologist (Author SS, see Table 1). The evaluation included administration of a symptom frequency questionnaire modified from the NIH Expert Panel Report 2 (NIH EPR-2), review of medication use, and a physical examination. Pulmonary function testing was carried out on children > 4 years of age using a computerized pneumotachometer (MultiSpiro). Based on the combined observations, an NIH EPR-2 asthma severity level was assigned.

**Table 1.** Summary of child asthma symptoms, asthma severity, and atopy for apartments enrolled in the study.

Family number	Asthma symptoms	Spirometry	Child skin sensitivities
1	None <sup>a</sup>	Moderate small airway obstruction, huge bronchodilator response.	Cat, Cockroach, Dust Mite, Grass Pollen, Horse, Mouse.
2	Daily <sup>b</sup>	Too young for spirometry.	Cat, Cockroach, Dust Mite, Fungi <i>Cladosporium</i> and <i>Aspergillus</i> , Ragweed Pollen.
3	Daily	Too young for spirometry	Cat, Dog, Dust Mite, Horse, Mouse, Tree Pollen.
4	Daily	Normal	Cockroach, Dust Mite, Tree Pollen.
5	Daily	Mild-to-moderate large and moderate-to-severe small airway obstruction.	Cat, Cockroach, Dust Mite, Fungus <i>Cladosporium</i> , Horse.
6	Daily	Mild large and severe small airway obstruction.	Dog; Dust Mite; Fungi <i>Alternaria</i> , <i>Aspergillus</i> , and <i>Cladosporium</i> ; Grass, Ragweed, Tree, and Weed Pollen; Mouse.
7	Two days per week	Mild large and moderate small airway obstruction.	Cat, Cockroach, Dog, Dust Mite.
8	Four days per week	No large, but moderate small airway obstruction.	Dog, Fungi <i>Alternaria</i> and <i>Cladosporium</i> , Horse.
9	Three days per week	Borderline large and mild-to-moderate small airway obstruction.	Cockroach, Dust Mite. <sup>c</sup>

a Uses bronchodilator 3x per day.

b Prior to preventive therapy being instituted.

c Benedryl<sup>®</sup> use may have suppressed reaction.

Allergy skin testing was performed using the MultiTest device (Center Laboratories, Port Washington, NY) with saline and histamine controls and 14 allergen extracts: cat; cockroach; dog; the dust mites *Der. Farinae* and *Der. Pteronyssinus*; the fungi *Alternaria*, *Aspergillus fumigatus*, and *Cladosporium*; horse; mouse; mixed tree pollens; mixed grass pollens; mixed weed pollens; and ragweed pollen. All allergen extracts were 1:20 (wt/vol) except for the dust mites, which were standardized extracts of 10,000 Allergy Units per mL. One panel of eight allergens was applied to the volar surface of each forearm using the method described in the package insert. Test results were read after 15 minutes by measuring and comparing the wheal for each antigen and for the controls. A test was considered positive if the wheal size elicited was at least 2 mm greater than the negative saline control.

## Intervention strategies



Three types of air filtration equipment were used in this study. Filtration equipment remained operational throughout the study; however, participants had access to the controls and could temporarily shut off fans or change fan speeds. The electronic polarization system consisted of an electrically charged glass fiber/activated charcoal filter, sandwiched between two screens. The main purpose of the activated charcoal is to distribute the electric charge efficiently throughout the media. The unit had a low 300 cfm setting and a high 500 cfm setting. The manufacturer estimated the unit's removal efficiency to be 80%, based on test results using room particulate, measured before and after filter installation with a P-TRAC Ultrafine Particle Counter (TSI Incorporated, Shoreview, Minnesota). The clean room filtration system consisted of wall-to-ceiling mounted units operating at 300 cfm. The units were equipped with a high efficiency particulate air (HEPA) filter and an ozone lamp followed by an activated charcoal filter. The system was designed to draw in room air at floor level and discharge filtered air at ceiling level. Two to three units were installed in each apartment. The HEPA filtration system is a commercially available small console, 300 cfm HEPA-filter unit. Maintenance was: clean room filtration system -- replace prefilter (40% efficiency standard size furnace filter 12 x12 x 1 in., \$2/filter) at 3-month intervals; electronic polarization system -- vacuum filter every month with HEPA-vacuum, replace filter every 2 months with manufacturer-supplied filter (\$10/ filter); and standard commercially available unit -- no maintenance, manufacturer's maintenance period is longer than study period.

Some tenants were provided with HEPA-filtered vacuum cleaners and asked, at least once a week or more frequently if desired, to vacuum floors, upholstery, and bedding throughout the house. The vacuum cleaners were equipped with on-off sensors placed inside their inner workings that will be retrieved at the end of the study. Bags were replaced once every 3 months and when requested by participants. Bags that were replaced were full, indicating at least some use.

An industrial cleaning machine applied an atomized water-based solution at 200 psi and was designed to extract, leaving little liquid in fabric, upholstery, and carpeting. It was used on floors, upholstered furniture, rugs, walls, windowsills, windows, interior of kitchen cabinets, and pantries. An attempt was made to clean stairwells; however, the stairwells remained clean only for a period of hours, and the effort required on stairwells was considerable. In addition, individual apartments were repaired and bedding covers or pest control devices were supplied as needed. Research staff HEPA-vacuumed the mattress covers and pillowcases prior to their installation. Participants were asked to place their own linens on top of both covers and cases and to change linens weekly. However, it was observed that some pillowcases were being used without exterior linens.

Apartments were assigned the following intervention regimes (apartment numbers correspond to those given in Table 1). Assignments were based on the apparent needs in each apartment as assessed during the initial visual inspection of each apartment.

- 1 Provided with an electronic polarization system. Industrial cleaning was done in months 1 and 4. Dust mite covers were put on five twin mattresses and a queen mattress, and eight dust mite pillow case covers were used. Openings under the sink and in the pantry were sealed with spray foam. Two ultrasonic pest repellent devices were installed. Exposed steam piping was insulated.
- 2 Provided with a clean room filtration system. Industrial cleaning was done in months 1 and 4. Dust mite covers were put on four twin mattresses and a queen mattress, and six dust mite pillow case covers were used. Openings under the sink and in the pantry were sealed with spray foam. Two ultrasonic pest repellent devices were installed. Exposed steam piping was insulated.



- 3 Provided with a clean room filtration system. Dust mite covers were put on two twin mattresses and a queen mattress, and six dust mite pillow case covers were used.
- 4 Provided with a HEPA filtration system. Dust mite covers were put on a twin mattress and two dust mite pillow case covers were used.
- 5 Provided with a HEPA filtration system. Industrial cleaning was done in month 1. Dust mite covers were put on two twin mattresses, and four dust mite pillow case covers were used. Two ultrasonic pest repellent devices were installed. Exposed steam piping was insulated.
- 6 Provided with an electronic polarization system. Industrial cleaning was done in month 1. Dust mite covers were put on a twin mattress and a queen mattress, and six dust mite pillow case covers were used. Openings under the sink and in the pantry were sealed with spray foam. Two ultrasonic pest repellent devices were installed. Exposed steam piping was insulated.
- 7 Tenants were provided with a HEPA vacuum.
- 8 Tenants were provided with a HEPA vacuum. Industrial cleaning was done in month 1. Dust mite covers were put on a twin mattress and a full mattress, and six dust mite pillow case covers were used. Openings under the sink and in the pantry were sealed with spray foam. Two ultrasonic pest repellent devices were installed.
- 9 Provided with an electronic polarization system. Dust mite covers were put on a twin mattress and a full mattress, and four dust mite pillow case covers were used.

## **Environmental observation and monitoring**

Monthly visits were made to each home from January through June 2000. During the visit to each of the nine homes, the study team made a visual inspection for mold, wetness, cockroaches, rodent droppings, etc. Each month, 24-hour time-integrated samples were passively collected for NO<sub>2</sub> using Yanagisawa Badges and were analyzed by light spectrophotometry.<sup>49</sup> Sampling for volatile organic compounds and particulate matter was also done, but results were not ready by the deadline for submission of this paper.

During each monthly visit, in each home, three vacuum samples of dust were collected. Dust was collected using a Eureka Mighty-Mite vacuum cleaner, modified to collect dust into a 19 x 90 mm cellulose extraction thimble (Whatman Inc., Hillsboro, OR). The first sample was a composite from the subject's room. It included the subject's bedding and carpeting around the subject's bed. This sample was analyzed for dust mite antigens Der p 1, Der f 1; Cat antigen Fel d 1; Dog antigen, Can f 1; and endotoxin (endotoxin was not ready by the submission deadline). A second dust sample was collected from the general living area. It was a composite of upholstered seating and carpeting. This sample was analyzed for dust mite antigens Der p 1, Der f 1; Cat antigen Fel d 1; and Dog antigen, Can f 1. A final vacuum sample from kitchen cabinets was analyzed for rodent antigen, Mus m 1 (Mus m 1 was not ready by the submission deadline); and cockroach antigen, Bla g 1. Dust mite, cat, dog, roach, and mouse antigens were analyzed using ELISA methods. Each antigen required 25 mg of fine dust.

To assay for molds, an aliquot of recovered dust was sifted (425 µm sieve) and 25 mg of fine dust was suspended in 2 mL 0.02% Tween 20 in distilled water for fungal analysis. This suspension was 10X serially diluted and 0.1 mL of each dilution (full strength -- 10<sup>-3</sup>) was spread-plated onto duplicated malt extract agar. Colony recoveries from the "optimal" dilution (that is, the dilution pair resulting in between about 10 and 100 colonies per plate) were counted and differentiated. Concentrations were calculated and reported as colony forming units per gram of dust.

Temperature and relative humidity measurements were collected continuously in the subject's room and the general living area using Onset Computer miniaturized data loggers.



## **Asthma diaries**

Parents and children (if the child was keeping the diary) were asked to evaluate the child's health daily with respect to asthmatic symptoms for three time periods: 1) between when they wake up and leave the home in the morning; 2) between when they arrive at home and go to bed; and 3) the overnight hours. They were to subjectively rate their health for the three time periods on a scale of 0 to 5, where 0 meant no symptoms and 5 meant severe symptoms. If they rated the time period something other than 0, they were asked to make an annotation, noting the symptoms. They were also asked to indicate how many hours were spent in the home. Diary results are not yet available.

## **Focus groups**

At the mid-point of the study, seven parents, representing seven of the nine enrolled families, attended a focus group run by one of the authors (DB). Parents from the other two families were interviewed separately by the same person. The focus group was designed to elicit a well-rounded description of experiences, difficulties, and recommendations. Discussion was prompted by the following topics, all of which were discussed, but not necessarily in sequence since participants sometimes raised issues before the moderator asked about them.

The focus group began with a warmup exercise in which participants said something about their experience having a child with asthma and why they decided to join the study. The ensuing discussion included the ease and/or difficulty with implementing the prescribed interventions. The moderator asked for a general sense of the parents' experience with the study and then probed for specific areas that might have been a problem, such as scheduling appointments with research staff and filling out the asthma diaries. Finally, participants were asked to indicate any ways that the program could have been made easier for them. The topic of industrial cleaning was raised in order to assess whether there was any resentment about having cleaning done in their apartments. The presence and sounds associated with filtering devices and monitoring instruments were raised and discussed. Resident perceptions about whether or not the interventions had helped their child's asthma were discussed. The participants in the focus group were asked to give their appraisal of the research staff.

The discussion was audio tape recorded and transcribed.

## **RESULTS AND DISCUSSION**

### **Observational lessons**

We found that younger children, under school age, tend to sleep with their parent, as well as in their own bed. This was significant because, in order to protect the child from dust mites associated with mattresses and pillows, the parent's bed as well as the child's bed should be taken into consideration. In addition to the child's and parent's bed, there were sometimes additional twin bed mattresses in the child's room that also required covering to make this intervention effective. Not covering all the mattresses would allow mite allergens to travel from bed to bed, and thus defeat the purpose of the intervention. Mattresses were stored on top of each other during the day, facilitating cross contamination.

The pest issue in the units was severe. The main pests observable from visual inspection were roaches and mice. The roaches tended to establish a base of operation inside the home either on top of the kitchen cabinets or in unused cabinets or drawers. Once the roaches infested a cabinet or drawer the



tenant would stop using that space because of the mass flight of roaches each time the cabinet or drawer was opened. As a result of the thorough cleaning of these units, these nests inside the apartment were removed, and the cockroach infestation in the apartments overall lessened. An effective pest management program should be included in any future study.

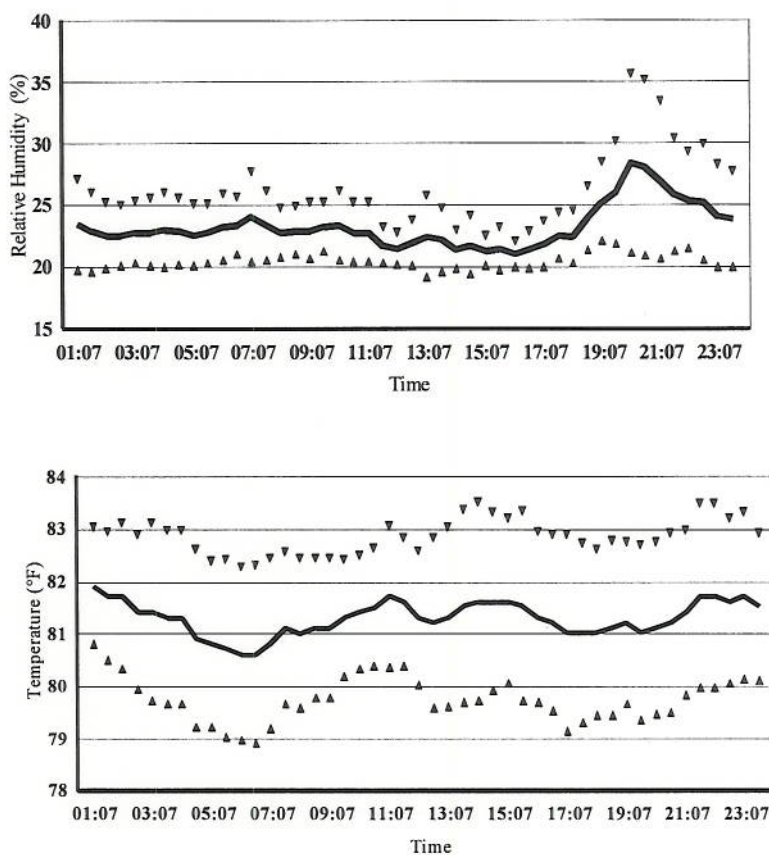
Most steam-heating pipes in these apartments were not insulated. Surface temperature measurements of these pipes were between 140° and 180° F. This posed a definite risk of burns for the occupants, particularly children. In addition, the lack of insulation on the piping made it impossible to manually control the heat inside the apartments. As a result, tenants would open all windows in winter, resulting in super-dry air (RH < 20%) inside the units (see Figure 1).

Mattresses and upholstered furniture in these units were very old, and thus had the potential to carry significant historical biological contamination. The residents, who have very limited financial capacity, often buy or inherit used furniture that may have had multiple previous owners and that probably carried a burden of antigens from the moment it was brought into the home. There is little in the cleaning capacity of the residents that would allow them to restore these furnishings to clean condition, should they even understand the problem and its potential relation to asthma.

Hallways had strong chemical or other odors. We attempted to remove these odors using our industrial cleaning machine. However, the hallways did not remain clean for any period of time, in part because there are not entrance doormats in any of the buildings to keep dirt from being tracked in from the street. We suspect that some of the chemical buildup is from cleaning solutions applied to attempt to deal with dirt and other contamination brought into the hallways.

The structure of the walls and ceiling in the units provided limited flexibility when designing mechanical interventions. The inner walls were not strong enough to support any weight. The outer walls were uninsulated brick walls with a plaster skim coat. The uninsulated outer walls were seen to be prone to condensation and mold growth in at least some apartments.

Tenants reported using their gas stoves for heating as well as cooking. Oven heating appears to occur primarily during the transitional weather in the spring and fall when central heating is sometimes turned on or off after or before the last cold spell. The practice of using ovens to heat the apartment can generate a significant health hazard from NO<sub>2</sub>.<sup>27</sup> In addition, the gas stoves are not ventilated or well-



**Figure 1.** Seven-day mean relative humidity and temperature for one public housing apartment from 2/01/00 to 2/07/00. Triangles represent one standard deviation.



insulated, resulting in overheating of the apartments while they are in use. Tenants also dry clothes inside the units, which could result in standing water and mold growth.

## Environmental conditions

The data that follow are only for baseline conditions; that is, conditions prior to intervention. Further, not all baseline data were available for inclusion. Excluded were analyses of mouse antigen, endotoxin, volatile organic compounds, and particulate matter.

### *Temperature and Relative Humidity*

Public housing residences in Boston are characterized by heating systems that allow for poor control of temperature, such that apartments are chronically overheated during the winter months. This results in resident complaints and reports of leaving windows open in cold weather to attempt to cool the apartments.<sup>48</sup> Figure 1 shows the temperature and relative humidity over 24 hour periods for 7 consecutive February days in one apartment enrolled in our study at baseline (prior to intervention). The readings indicate that temperatures are high and relative humidity very low.

### *Mold*

Numerous fungal genera have been associated with asthma in the literature, including *Alternaria*, *Aspergillus*, *Bacillus*, *Cladosporium*, *Mucor*, *Penicillium*, *Rhizopus*, and *Ulocladium*.<sup>27,50</sup> Sensitization is apparently higher in younger persons, notably 14-19 years of age.<sup>51</sup> Fungi may produce toxins, but are thought to aggravate asthma primarily via aeroallergens, such as proteinases.<sup>52,53</sup> There is not yet a generally agreed upon standard against which to measure levels of fungus in the home with respect to development or exacerbation of asthma.<sup>27,54</sup> Table 2 presents baseline data for viable mold in settled house dust averaged for 10 samples taken from 6 of the apartments enrolled in our study. Note that measurement of viable spores may underestimate allergen exposure, and measurement of settled dust does not necessarily reflect airborne, respirable burden.<sup>27</sup> Further, there may be considerable variation in viable spores over short periods of time.<sup>54</sup> Table 2 shows that there was a wide range of viable spore counts between the apartments in our sample, and that species thought to have the potential to play a role in asthma and allergy were present in many apartments.

### *Antigens*

Antigens inside the home associated with dust mite (Der p I, Der f I), cat (Fel d I), cockroach (Bla g I), and to a lesser extent, Dog (Can f I) have been associated with allergic sensitization and asthma. A threshold for sensitization to dust mite antigen has been suggested to be 2 µg/g. Exposure to cockroach antigen above 1 U/g has been reported to cause sensitization. It is also worth noting that cat and dog antigen is more easily aerosolized than dust mite or cockroach antigens, making settled dust measurements less reliable for estimating exposure.<sup>27</sup> It has been suggested that cockroach may be the most significant of these antigens for inner-city children.<sup>19</sup> Our preliminary data, presented in Table 3, suggest that dog, cat, and dust mite antigen levels were moderate to low, while cockroach antigen levels were extremely high. A high cockroach antigen level is consistent with our observational data, while any pet antigens would be acquired either from outside sources or pets kept against the development's no pet policy.

Wood et al. reported antigen and mold levels in settled house dust in Baltimore.<sup>55</sup> The similarity of the biological parameters that they measured to those we measured is worthy of comparison. They reported



median total dust mite antigen to be 1.1 µg/g, median dog antigen 2,719 IU/g and median cat antigen 0.09 µg/g. Median mold levels were reported to be 2400 cfu/g. Rosenstreich et al.<sup>19</sup> reported median and maximum antigen levels for children in inner-city residences. They found median and maximum cockroach antigen levels to be 8.2 and 1,190 U/g, dust mite antigen levels to be 0 and 39 µg/g, and cat antigen levels to be 0.09 and 167 µg/g, respectively. The values that we report here are broadly consistent with these values, albeit we found cockroach antigen to be much higher and dog antigen to be much lower.

**Table 2.** Reported below are speciation and total colony forming units (cfu) for settled house dust collected from bedrooms and living rooms prior to intervention from public housing apartments enrolled in the study. Duplicate analyses of each of 10 dust samples taken from 6 apartments were averaged. The lower limit of detection was 40 cfu/g house dust.

Species	Average cfu/g fine dust	Range cfu/g fine dust
<i>Acremonium</i>	0	0
<i>Alternaria</i>	440	0-2400
<i>Aspergillus, other</i>	800	0-8000
<i>Aspergillus, flavus</i>	680	0-3200
<i>Aspergillus, fumigatus</i>	0	0
<i>Aspergillus, glaucus</i>	360	0-3200
<i>Aspergillus, nidulans</i>	0	0
<i>Aspergillus, niger</i>	1120	0-16000
<i>Aspergillus, ochraceus</i>	400	0-8000
<i>Aspergillus, versicolor</i>	400	0-8000
<i>Aureobasidium</i>	1080	0-4000
<i>Botrytis</i>	0	0
<i>Clad sporium</i>	1960	0-16000
<i>Coelomycetes</i>	3800	0-19200
<i>Curvularia</i>	0	0
<i>Epicoccum</i>	0	0
<i>Fusarium</i>	120	0-1600
<i>Paecilomyces</i>	200	0-3200
<i>Penicillium</i>	1200	0-8000
<i>Pithomyces</i>	0	0
<i>Trichoderma</i>	40	0-800
<i>Ulocladium</i>	80	0-800
<i>Wallemia</i>	40	0-800
<i>Yeast</i>	4880	0-24000
<i>Zygomycetes</i>	1600	0-16000
<i>On-Sporulativ</i>	4360	0-32000
Total (in any individual apartment)	23600	4800-104000

### Nitrogen Dioxide (NO<sub>2</sub>)



A recent review concludes that indoor sources can be the primary cause of exposure to NO<sub>2</sub>.<sup>27</sup> Surveys and observational evidence suggest that the gas ovens in public housing apartments in Boston are used for supplemental heating, particularly at the start and end of the heating season when institutional heat may start late or end early from the perspective of the tenants.<sup>48</sup> In addition, the poor ventilation in these buildings and lack of exhaust systems above stoves have the potential to lead to buildups of NO<sub>2</sub> at other times of the year. Table 4 presents NO<sub>2</sub> measurements for seven of the apartments in our study. All of our measurements were either close to or exceeded the U.S. EPA National Ambient Air Quality Standard of 50 ppb for NO<sub>2</sub>. The arithmetic mean of 1-hour NO<sub>2</sub> concentrations for the air monitoring station closest to the Franklin Hill public housing in Boston was 31 ppb, with a maximum of 79 ppb for the period January 1 through May 23, 2000.<sup>56</sup> Kitchen levels of NO<sub>2</sub> during cooking have been reported as high as 400 ppm.<sup>27</sup> It is likely that our baseline sampling period missed use of ovens for heating since it was mid-winter and overheating was generally pervasive.

**Table 3.** Dust mite (Der p I, Der f I), cat (Fel d I), dog (Can f I), and cockroach (Bla g I) antigen levels in settled house dust prior to intervention from public housing apartments. Values are averages with the number of samples in parentheses (n). For samples below the limit of detection (LOD), the LOD was used.

Room	Der f I (μg/g)	Der p I (μg/g)	Fel d I (μg/g)	Bla g I (U/g)	Can f I (IU/g)
Bedroom	0.34 (6)	0.15 (6)	0.80 (6)	ND <sup>a</sup>	77.26 (6)
Living room	0.53 (7)	0.11 (6)	0.80 (7)	ND	50 <sup>b</sup> (6)
Kitchen	ND	ND	ND	846.60 (6)	ND

a ND = not determined.

b All values were below the limit of detection (50 IU/g).

**Table 4.** One-day NO<sub>2</sub> levels measured in seven public housing apartments in February 2000.

Apartment	Sampling period (hr)	ppb
1	24.5	75
2	24	47
3	23	59
4	24	52
5	24	59
6 <sup>a</sup>	24	49
6 <sup>a</sup>	24	54
7	24	67

a The two samples in apartment 6 are duplicates, to provide a measure of precision.

### *Resident satisfaction/participation*

Prior to conducting our focus group with parents of children enrolled in the study, we had each parent fill out a short questionnaire, on which they did not include their name or any other identifier (Table 5). The responses suggest a general level of satisfaction with participation in the study. Filling out the asthma diaries was the most problematic aspect of their participation. There is also some suggestion that scheduling was a problem, at least for some families. These and other themes were explored in more depth in the focus group.

The focus group largely confirmed a general sense of satisfaction with the program. This was expressed most strongly as a desire, felt by all of the participants, that the program be extended and disappointment



that it would not after funding expires. Parents were largely convinced that the interventions that they had received were helping their asthmatic children. When pressed for concrete evidence of this, two parents reported that emergency room visits had declined since the intervention was started in their apartment. When asked whether the program requirements -- installation of the intervention, having monitoring done in the apartment each month (including sampling household dust), keeping asthma diaries -- were a problem, only the asthma diaries were considered problematic. While noise from the monitoring equipment bothered some parents, they viewed it as a small inconvenience compared to what they perceived as the benefits of the program. One parent disliked a local resident that we hired to assist the research staff, but both she and the other parents were uniformly complimentary about the lead field researcher (author JV).

**Table 5.** Responses of participating parents to a questionnaire about the study program (n=9).

Question	Number responding "yes" (missing)
Prior to starting, did you think that this program could help your child control their asthma?	9 (0)
Do you now think that the program has helped your child with respect to their asthma?	9 (0)
Overall, would you say that the program was easy to do?	9 (0)
Was scheduling a problem because of job/children/life?	3 (0)
Was filling out the diaries hard to remember to do?	7 (1)
Did you mind having the monitoring done each month?	1 (0)
Rated research staff excellent	5 (0)
Rated research staff good	3 (0)
Rated research staff poor	1 (0)

It is tempting to ask what led to success in terms of the recruitment, retention, and acceptance of the residents that we worked with. Work with inner-city, low socio-economic and minority populations has frequently proven to be challenging for university researchers.<sup>57</sup> Our approach followed the general method described by Hynes et al.<sup>48</sup> We propose two key factors that contributed to our success in positively engaging residents. The first is that we collaborated with a community partner, the Committee for Boston Public Housing (CBPH), that had strong ties to residents in the development. CBPH had residents who were in their Action Against Asthma Health Advocate Training Certificate Program assist with recruitment, scheduling, and retention. By creating a partnership with the community, we diffused some of the wariness and skepticism that residents would normally have for outside parties.

Even so, recruitment was slow and two of the families enrolled will have completed only 3 months of the planned 6-month intervention by the end of the study period. Some of the reasons for this are beyond our control. Many residents of public housing face complex circumstances that limit their ability to join a research study or even to participate in a non-research program aimed at addressing asthma. To cite one example, a parent approached us during the recruitment phase with strong interest in participating, but ultimately could not do so because she was under emergency orders for relocation due to a domestic violence situation.

Secondly, we think that the style and attitude of our lead field researcher contributed to acceptance. He had an ability to explain the project clearly in lay terms and to relate easily to the residents. The residents value relationships above most other considerations, so making a personal connection with



them improves the dynamic considerably. For example, we were told before starting and had heard from other work in public and low income housing that residents would be resistant to suggestions that their cleaning methods were a problem and, by extension, causing their child's asthma. The lead field researcher defused this potentially charged issue by separating routine cleaning by the residents from what we were doing. He named the industrial cleaning, "decontamination" and spoke about levels of contamination in, e.g., old upholstered furniture that could not be removed by any method at the disposal of the residents. By also being very responsive to the concerns of the residents, he built a level of trust that likely contributed to successful collaboration with the residents.

The lessons that we report here are more specific, but not in contradiction to those reported by the National Cooperative Inner-City Asthma Study.<sup>57</sup> That report involved 1337 children with only a baseline survey and three followup assessments, including asthma diaries, without the aggressive interventions that we employed. They obtained 88.8% completion of all assessments, but only 41.7% completion of the diaries. Like us, they found the resource commitment necessary to gain such levels of participation quite high. They estimated that had they not done in-person followups and had limited phone calls to three attempts that their completion rate for assessments would have dropped to 63%. Lower completion rates were found for Blacks, for those with incomes under \$15,000 per year, and high family stress scores. All of these describe the families that we worked with.

### ***Creating Jobs for Residents***

Despite the limited nature of our pilot study, we considered this an opportunity to test whether or not we could hire persons out of the community to assist with various parts of the project. In this spirit, the Harvard School of Public Health hired one resident to work in their laboratory, initially on a trial, part-time basis and ultimately as a full-time permanent employee. In addition, the field team hired a relative of one of the families enrolled in the study on a part-time, temporary basis to help with installing and maintaining the interventions.

### **Conclusions**

We were largely successful at engaging residents of public housing in an asthma intervention study. Even so, it is important to note that our success came at the price of expending considerable time and resources. The community partner, their resident Asthma Advocates, and the university partners had to work hard at generating interest and participation. Relationship building and partnering with the community were key features of our effort that led to resident support for the project. As a result of successfully engaging these nine public housing families, we have been able to gather more dense environmental data and install more extensive interventions than have other studies of inner-city populations. Reported above were baseline data, which suggest that overheating, low RH, fungi (in some apartments), cockroaches, and NO<sub>2</sub> are of greatest concern. These findings are preliminary, but it is striking that, where they overlap, they are largely in agreement with other studies reported in the literature. When combined with the longitudinal data following intervention, we hope to be able to generate hypotheses for further and larger scale investigation.

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