Review of Assessment Methodologies Used in Ten Studies of the Home Environment of Asthmatic Children Final Report

This Healthy Homes Technical Studies project will synthesize complex data from ten studies in order to identify visual assessment protocols, questionnaires, environmental testing and other tools that are most predictive of childhood asthma and to develop a standardized home assessment for asthma. This report compares and contrasts the methods used in each study as a preliminary step in determining which tools are most useful. Additional statistical analyses will be done to augment this preliminary qualitative review to help determine which measures (and combinations of measures) can be used to predict children's asthma control.

Boston Medical Center (Boston), Boston Public Housing Authority/Harvard (Harvard), Cincinnati Children's Hospital (Cincinnati Asthma Prevention Study, or CAPS), and Johns Hopkins University (Hopkins) each contributed data from a single asthma study to this project, while Case Western Reserve (Cleveland), Columbia University, and Seattle-King County Public Health (Seattle) each contributed data from two studies, yielding a total of ten studies conducted at seven sites across the country. Information for these 10 studies was gleaned from study protocols, interviews, data collection forms and published articles (Eggleston et al., 2005b, Takaro et al., 2004, Krieger et al., 2005, Levy et al. 2004, Clougherty et al. 2006, Levy et al. 2006).

1. RECRUITMENT

The overall design of each of the ten studies is summarized in Table 1. Eight of the studies were randomized clinical trials (RCTs); two were non-randomized studies, and one was a birth cohort study. RCTs have the advantage of helping to determine which interventions are associated with outcomes and help to control confounding influences. However, RCTs may not be representative of non-research settings, because the degree of oversight for both the experimental group and the control is greater than a typical patient may receive. Although the eligible age ranges of children varied somewhat across studies, most sites recruited children of elementary to high school age, when asthma symptoms could be more readily observed compared to younger age groups. Physician-diagnosed asthma was a requirement for enrollment into all but the birth cohort study. At least two sites (Cincinnati and Hopkins) further restricted enrollment based on other health criteria, e.g., no other respiratory diseases, no congenital heart disease, current symptoms or medication use in the previous 3 months, etc. Such enrollment criteria could be expected to reduce the influence of confounding variables, but they could also be expected to add complexity to the enrollment process, increase the time involved and perhaps reduce cohort size. Most sites recruited children and homes from inner city, low-income urban areas. Sample sizes for each study ranged from 62 to 326 children.

Most studies recruited dwellings from a set geographic area within their region. Due to the types of planned interventions, dwellings in several studies had to meet specific requirements such as having electricity, evidence of mold/moisture problems, or cockroach infestation. The types of houses enrolled likely varied considerably based on these enrollment requirements. For

example, cockroach infestation was an eligibility requirement for homes in the Columbia University integrated pest management (IPM) study in order to study the effectiveness of such pest treatments, while Cincinnati and Johns Hopkins needed homes to have electricity so that air purifiers could be used. Both studies done by Cleveland were designed to reduce mold and moisture problems in housing; therefore, dwellings had to have evidence of water damage or mold growth in order to be enrolled. Variability in enrolled housing units has the advantage of ensuring a wider range of potential exposures, improving the prospect of elucidating dose/response functions. At the same time, such variability makes uniform housing interventions more difficult. Columbia University's birth cohort study was the only one that was not an intervention study.

2. HOME EVALUATION PROCEDURES

2.1. Visual Assessment/Questionnaires

All ten of the studies used different inspection checklists to allow an investigator to visually assess baseline characteristics and conditions of enrolled dwellings. In eight of the ten studies, residents provided additional housing information through questionnaires/interviews. No standard references existed for the visual assessment tools. Although the level of detail and the specific items included on the visual assessment tools varied considerably across sites, as shown in Table 2, the majority of tools included many common items that allowed the inspector to assess building characteristics such as building type, age, location, type of heating/cooling systems, overall condition (state of repair), visible evidence of pests, evidence of pets, and the presence of excess moisture/mold/water damage.

Questionnaires generally included housing-related questions that could not be otherwise easily assessed by inspectors, such as questions concerning resident cleaning behaviors, pest control measures undertaken by residents in a previous period of time, and food debris/storage behaviors. Some questions (e.g., visible evidence of pests and pets, mold/moisture problems, etc.) tended to be asked on both visual assessment and questionnaire tools, with the visual assessment used to corroborate answers given on the questionnaire.

2.2 Environmental Sampling and Analysis Procedures

All ten studies collected and analyzed environmental samples as part of their evaluation of the baseline home evaluation. These data were generally collected in order to characterize exposure to given substances before interventions began. As shown in Table 2, the types of samples collected (e.g., settled dust by vacuum, settled dust by wipes, air, etc.) and the types of analytes (e.g., allergens, molds, pesticides, etc.) varied considerably across studies.

2.2.1 Settled Dust

2.2.1.1. Allergens

There were substantial differences in the way various sites collected and handled settled dust allergen samples. Allergens were by far the most common settled dust analytes studied. All ten

studies collected settled dust samples using vacuum methods and analyzed them for allergen content using standard enzyme-linked immunosorbent assay (ELISA) techniques. Hopkins reported that they collected dust samples according to methods provided in Platts-Mills et al. (1992) and Wood et al. (2001), but there are currently no widely accepted standard settled dust sample collection methods for allergens. Therefore, the choice of sampling materials and sampling methods varied widely among studies. For example, at least three different types of portable vacuum cleaners and sample collection devices were used in various studies to collect settled dust samples. Differences in flow rates and sample collection efficiencies are likely to yield differences in the quantities of dust collected within a given timeframe, as well as different particle size distributions. Variability in particle sizes collected may mean that the biologically relevant fraction of settled dust may be undersampled, thus reducing the degree of correlation observed between environmental levels and asthma status. There was little information available on the specific procedures used to vacuum the floor surfaces; however, at least one study (Cleveland) reportedly sampled each area twice, first in one direction, then in a direction perpendicular to the first. This can be expected to improve sample collection efficiency and add stability to environmental levels, especially when they are expressed in loading as opposed to concentration. In the Cincinnati study, areas were sampled in one direction only, but in overlapping "passes" as the sampler moved across the sample area. For the two Seattle studies, the standard method involved using overlapping passes, with eight passes in each segment. This lack of uniformity in coverage of specific surface areas can be expected to affect the stability of loading (i.e., weight of analyte per surface area) metrics, but perhaps less so when analytes are reported in concentration (weight of analyte per weight of total dust collected). This in turn may affect the degree of correlation and other measures of explanatory power with asthma onset and exacerbation.

A variety of room types and surface types were sampled in the various studies. For example, only four of the ten studies collected baseline settled dust samples from kitchen floors. When studies collected samples from kitchen floors, they tended to sample all exposed surface areas of the floor. Major play areas (variously defined as living rooms, play rooms, main activity rooms, and TV rooms) were sampled in seven of the ten studies. The floor was the primary surface sampled in these play areas, with upholstery sampled in only one study.

The index child's bedroom was a common sample location, sampled in each of the ten studies; however, some studies collected samples only from bedding, others collected only from floors, others collected separate samples from both, and at least one combined the floor and the bedding sample into one collection device. The dimensions of the floor sampled and the time taken to collect the sample varied across sites but, in general, between 1 and 3 m^2 of floor area was sampled for 2 to 3 minutes/m^2, with some studies sampling all exposed areas of bare floors. At least one study specifically required that the bedroom floor sample be taken near and/or under the bed, while other study protocols did not specify a particular floor location within the bedroom. Samples collected close to or under beds may be expected to contain higher concentrations of allergens such as dust mite allergens since the bed is the primary source of such allergens. Four studies included some type of bedding samples. Based on the materials provided, it is not possible to discern differences or commonalities between the bedding components sampled in the different studies.

Preparation of collected dust also varied between studies. For example, in the two Columbia University studies, no sieving of collected dust was performed prior to extraction, while the Hopkins study used a 300-um sieve size and the two Seattle studies used a 150-um sieve size. The impact of these differences in sieving methods on allergen analytical results is not known although they would certainly yield different quantities of sieved dust available for extraction and can also be expected to have differing degrees of biological relevance, since the smaller particles may be more likely to be ingested and/or inhaled and absorbed. Most studies kept samples cold during shipment to the laboratory, stored the dust samples at temperatures ranging from -4 degrees C to -20 degrees C, and stored extracts at -20 to -30 C.

In all 10 studies, sample extracts were analyzed for allergens using standard ELISA methods (Platts-Mills et al., 1992, Chapman et al., 1988, Pollart et al., 1991, Ohman et al., 1991). The rationale for the selection of particular allergen analytes for particular studies was not provided. Dust mite and cockroach allergen were the most common allergen analytes. All studies included dust mite allergen(s); however, while six of the ten studies analyzed samples for both der f1 and der p1 separately, two studies analyzed only for der f1 and two other studies for der p1. Nine of the ten studies included cockroach allergen(s), with three studies separately analyzing both bla g1 and bla g2, four studies analyzing only for bla g1, and two studies analyzing only for bla g2. Seven of the ten studies included mouse allergen, with four analyzing samples for mouse urinary protein (MUP) and 3 analyzing for mus m1. Seven studies included cat allergen (fel d1), and five included dog allergen (can f1) as analytes. The two Cleveland studies were the only studies to analyze settled dust samples for rat urinary protein (rat n1).

All of the studies provided allergen results in terms of the specific allergen concentration (e.g., micrograms der f1 per gram of sieved dust), and four sites also reported results in terms of allergen loading (e.g., micrograms der f1 per ft^2 of floor space sampled). Loading may be a better measure of exposure than concentration, since it reflects both the concentration of the allergen in dust and the amount of dust (and therefore allergen) present on the sampled surface. Loading is dependent on the type of vacuum nozzle, type of vacuum, flowrate, accuracy and precision of measurement of the surface area , uniformity of contact between the sampling inlet and the surface area, the amount of time taken to sample a specific area, and the type of flooring and/or floor covering. Since these parameters vary greatly across sites, dust concentration results may have fewer sources of error and are therefore thought to be a more repeatable (precise) measure. In addition, allergen level cutpoints or thresholds, expressed in units of concentration and based on asthma severity, have become increasingly accepted within the research community and are useful ways to compare allergen concentration data across studies.

2.2.1.2 Other Analytes in Settled Dust

In addition to allergens, a few studies analyzed settled dust samples for other analytes such as endotoxin (three studies), beta-glucan (two studies), pesticides (four studies), ergosterol as a fungal biomarker (one study) and mold (two studies); however, because these analytes were included in only a few of the ten studies, they are not discussed further in this report.

2.2.2 Air

Seven of the 10 studies conducted ambient air sampling for their studies; however, the analytes for these air samples varied widely between studies. Airborne allergen samples were the most common of the air samples collected, but they were collected in only four studies, with the types of allergen analytes and sample collection methods varying across the four studies. Airborne mold spore counts were collected only in the two Seattle studies. Airborne particulate (PM10 and/or PM2.5) was measured in four studies, nitrogen dioxide in three studies, ozone and nicotine in one each. Most studies that took temperature and relative humidity measurements in the home used real-time instruments that recorded these measures at a specific point in time. In the National Survey of Lead and Allergens in Housing (Arbes et al., 2003), single humidity readings were correlated with dust mite allergen levels. However, as shown in Table 2, no two studies measured temperature and humidity in the same manner, limiting the data's usefulness in evaluating whether or not there is a dampness problem in a dwelling over a sustained time period or evaluating any correlations between humidity and allergen levels.

2.2.3 Surface Moisture

The surface moisture content of various indoor building components was tested in only three studies. The two Cleveland studies measured the moisture content of surfaces with signs of moisture damage and the Hopkins study measured surface moisture content of four walls per dwelling.

3. HEALTH AND QUALITY OF LIFE ASSESSMENT PROCEDURES

3.1 Questionnaires/Interviews

All ten studies used some type of standardized, interviewer-administered baseline health survey to obtain health information about enrolled participants (Table 3). The National Cooperative Inner-City Asthma Study (NCICAS) health survey (Mitchell et al., 1997), variations of which were used by two studies (Boston and Hopkins), is based on a multi-site database with a large cohort and was designed primarily for research, not clinical, purposes (Swartz et al., 2004, Mitchell et al., 1997, Juniper et al., 1996a, Juniper et al., 1996b, Radloff et al., 1977). The National Asthma Education and Prevention Program (NAEPP) health survey, used only in the two Seattle studies, is a consensus document that was originally designed to be used by clinicians to categorize asthma severity. Seattle also measured caretaker quality of life using and quality of life for older children using Juniper tools. Eggleston et al (2005a) stated that since daily asthma medications have become more common, the NAEPP scale "has been felt to more appropriately describe disease control rather than asthma severity."

The Children's Health Survey for Asthma (CHSA, Asmussen et al., 1999), used in the two Cleveland studies and the Cincinnati study, is a standardized, validated tool that combines the assessment of asthma severity and quality of life. Both the NCICAS and the CHSA tools have questions that are based on a 2-week time period; however, several studies reported that their questions used a different timeframe (e.g., 4 weeks, past 3 months, etc.). The CHSA tool has separate questions concerning wheezing versus coughing versus chest tightness, while the

NCICAS tool combines these into a single question. There are advantages and disadvantages for the longevity of time period. For example, longer time periods yield a greater likelihood of capturing more incidents. On the other hand, respondents may have imprecise recollection of events over longer time periods, especially for moderate or mild symptoms.

Regardless of the specific tool used, health surveys for all ten studies included questions concerning asthma disease activity, typically measured through questions concerning day and nighttime symptoms, medication use (including medications for symptoms, control medication, and oral steroid use), health care (e.g., emergency department visits, clinic visits, hospitalizations, etc.), allergy history, and family history. The specific phrasing of these questions differed across studies, with some studies utilizing a yes/no structure to answer questions, and others using a "frequency of occurrence" structure, with the time frame (i.e., in the past two weeks, past 3 months, past 12 months, etc.) varying between the studies. For example, all studies asked questions concerning the use of rescue medications; however, most only asked whether or not such medications had been used, not about the frequency of use, making it difficult to use rescue medication as an outcome measure in statistical analyses when the rescue medication is described as a continuous (instead of categorical) variable.

3.2 Clinical Measures

All ten studies performed one or more clinical tests on enrolled children (Table 3). The most common test, conducted by six of the ten studies, was a pulmonary function test (PFT) used to obtain FEV1 and/or peakflow values. FEV1 a useful measure for assessing airway obstruction in children 5 years of age of older, while peakflow is not considered as strong an outcome measure as FEV1. PFT has the advantage of being easy to administer outside clinical settings, i.e., in the home.

Sensitivity to specific allergens was tested in nine of the ten studies, either by radioallergosorbent tests (RAST) blood tests (i.e., serum IgE) or by skin prick testing. These tests were conducted to determine that enrolled children were atopic and to determine sensitivity to the indoor allergens measured during indoor environmental sampling. As noted in Eggleston et al. (2005a), high concentrations of indoor allergens combined with specific IgE to such allergens is the strongest known risk factor for asthma severity and morbidity. Skin tests have the advantage of being convenient, much less expensive than RAST tests, well-tolerated, require a lower level of blood-borne pathogens precautions than RAST testing, and are accurate even in small children; however, they do have a low risk of introducing potentially hazardous substances to the body, and they leave an itching sensation that may take 1 to 2 hours to dissipate. RAST blood tests are advantageous because they are less invasive (e.g., one venipuncture vs. several skin pricks, although some people feel that a needle is more painful than multiple scratches), and skin conditions do not interfere with results. In one study, skin test responsiveness to ragweed correlated with blood ragweed-specific IgE levels; however, the study noted that these two types of test do not equally measure the degree of allergic sensitivity (Stokes et al., 2005).

Urine testing was conducted in four studies. Cleveland collected urine samples to determine if the child was exposed to environmental tobacco smoke (i.e., through urine cotinine tests). Cincinnati collected serum and hair samples to test for cotinine.

Other health tests were conducted far less frequently than blood and urine testing. Nasal wash testing for leukocytes and fungi was conducted only by Cleveland. Expired nitrogen dioxide tests were conducted only in the Cincinnati study as a measure of exposure to environmental tobacco smoke.

4. CONCLUSIONS

As shown in this review, asthma studies vary widely in their approaches, protocols, and procedures for gathering and analyzing data. Quantitative statistical analysis of the ten studies will help determine which measures (and combinations of measures) can best be used to predict children's asthma status and to predict settled dust allergen levels in homes of asthmatic children.

5. REFERENCES

Arbes SJ, Cohn RD, Yin M, Muilenberg ML, Burge HA, Friedman W, and Zeldin DC. House dust mite allergen in US beds, results from the first National Survey of Lead and Allergens in Housing. J. Allergy Clin Immunol 2003;111(2):408-414

Asmussen L, Olson LM, Grant EN, Fagan J, Weiss KB. Reliability and Validity of the Children's Health Survey for Asthma. Pediatrics 1999;104:e71.

Chapman MD, Aalberse RC, Brown MJ, Platts-Mills TAE. Monoclonal antibodies to the major cat allergen fel d I, II: single step affinity purification of Fel d I, N terminal sequence analysis and development of a sensitive two-site immunoassay to assess Fel d I exposure. J Immunol 1988;140:812-821

Chew GL, Correa JC, Perzanowski MS. Mouse and cockroach allergens in the dust and air in northeastern United Stated inner city public high schools. Indoor Air 2005; 15(4):228-334.

Clougherty JE, Levy JI, Hynes HP, Spengler JD. A longitudinal analysis of the efficacy of environmental interventions on asthma-related quality of life and symptoms among children in urban public housing. J Asthma 2006;43:335-343

Eggleston PA, Diette G, Lipsett M, Lewis T, Tager I, McConnell R, Chrischilles E, Lanphear B, Miller R, Krishnan J. Lessons learned for the study of childhood asthma from the Centers for Children's Environmental Health and Disease Prevention Research. Environ Health Perspect 2005a;133(10):1430-6

Eggleston PA, Butz A, Rand C, Curtin-Brosnan J, Kanchanaraksa S, Swartz L, Breysse P, Buckley T, Diette G, Merriman B, Krishnan JA. Home environmental intervention in inner-city asthma: a randomized controlled clinical trial. Ann Allergy Asthma Immunol 2005b;95:518-524

Juniper EF, Guyatt GH, Feeny DH, et al. Measuring quality of life in parents of children with asthma. Qual Life Res 1996a;5:27-34

Juniper EF, Guyatt GH, Feeny DH, et al. Measuring quality of life in children with asthma. Qual Life Res 1996b;5:35-46

Krieger JW, Takaro TK, Song L, Weaver M. The Seattle-King County Health Homes Project: A randomized, controlled trial of a community health worker intervention to decrease exposure to indoor asthma triggers. Amer J Public Health 2005;95:652-659

Levy JI, Brugge D, Peter JL, Clougherty JE, Sadler SS. A community-based participatory research study of multifaceted in-home environmental interventions for pediatric asthmatics in public housing. Soc Sci Med 2006;63:2191-2203

Levy JI, Welker-Hood LK, Clougherty JE, Dodson RE, Steinbach S, Hynes HP. Lung function, asthma symptoms, and quality of life for children in public housing in Boston: A case-series analysis. Environ Health: A Global Access Science Source 2004;3:13

Mitchell H, Senturia Y, Gergen P, Baker D, Joseph C, McNiff-Mortimer, K, Wedner JH, Crain E, Eggleston P, Evans R, Kattan M, Kercsmar C, Leickly F, Malveaux F, Smartt E, Weiss K. Design and Methods of the National Cooperative Inner-City Asthma Study. Pediatr Pulmonol 1997;24:237-252

Ohman JL, Hagbeerd K, MacDonald MR, et al. Distribution of mouse allergen in a major mouse breeding facility. J Allergy Clin Immunol 1991;94:810-817

Platts-Mills TA, Thomas WR, Aalberse RC, et al. Dust mite allergens and asthma: report of a second international workshop. J Allergy Clin Immunol. 1992;89:1046-1060

Pollart SM, Smith FT, Morris EC, et al. Environmental exposure to cockroach allergens: analysis with monoclonal antibody-based enzyme immunoassay. J Allergy Clin Immunol 1991;87:505-510

Radloff LS. The CES-D scale: a self-report depression scale for research in the general population. Appl Psychol Meas 1977;1:385-401

Stokes J, Kessler R, Philip G, Gasale T. Ragweed skin test responsiveness correlates with specific immunoglobulin E levels. Allergy and Asthma Proceedings, 2005;26(2):p103-107

Swartz L, Callahan KA, Butz AM, et al. Methods and issues in conducting a community based environmental randomized trial. Environ Res 2004;95:156-165

Takaro TK, Krieger JW, Song L. Effect of environmental interventions to reduce exposure to asthma triggers in homes of low-income children in Seattle. J Exposure Analysis and Environ Epidemiol 2004;14:S133-S143

Wood RA, Eggleston PA, Rand C, Nixon WJ, Kanchanaraksa S. Cockroach allergen abatement with extermination and sodium hypochlorite cleaning in inner-city homes. Ann Allergy Asthma Immunol 2001;87:60-64

Table 1: Overview of Study Designs									
Name of Study	**Boston HH Partnership (Boston)**	**Boston Healthy Public Housing Initiative (Harvard)**	**Urban Mold & Moisture Prog. Composite (Cleveland Composite)**	**Urban Mold & Moisture Prog. Asthma Study (Cleveland Asthma)**	**Cincinnati Asthma Prevention Study (Cincinnati)**	**Reducing Indoor Allergen Exposures in Northern Manhattan and the South Bronx (Columbia IPM Study)**	**Socio-Cultural Influences on Allergic Sensitization (Columbia Birth Cohort)**	**Childhood Asthma in the Urban Environment (Hopkins)**	**Seattle-King Co. Healthy Homes 1 (HH1) & Healthy Homes 2 (HH2) (2 studies)**
Partner	Boston Medical Center	Boston Public Housing Authority (Harvard)	Case Western Reserve/Cuyahoga County	Case Western Reserve/Cuyahoga County	Cincinnati Children's Hospital	Columbia Univ	Columbia Univ	Johns Hopkins	Seattle Public Health
Type of Study	Randomized controlled trial	Non-randomized intervention study	Observational-no randomization	Randomized controlled trial	Randomized controlled trial	Randomized controlled trial	Birth cohort	Randomized controlled trial	HH1: Randomized controlled trial HH2: Randomized controlled trial
Sample Size (baseline)	267 children	79 children	69 total: 13 children with asthma; 56 children without asthma	62 children	225 children	31 children	274 Homes	100 homes w/100 children	HH1: 294 children, HH2: 326 children
Eligibility	0-17 years; Phys. diag. asthma; Non-public housing; d.u. needs <$20K in repairs	4-17 years phys. diag. asthma Reside in Boston PH	Infants and children suffering from or at risk for respiratory health problems d.u. has evid of water damage/mold growth	2-17 years phys. diag. asthma Moderately severe asthma with 1 hospitalization or 2 acute sick visits in past year d.u. has evid. of water damage/mold growth	6-12 years phys. diag. asthma expos. to ≥ 5 cigarettes/day home w/electricity no other resp. disease, no congenital heart disease, no mental retardation, no neuromuscular disease	5-18 years phys. diag. asthma pos. cockroach skin test d.u. has cockroaches	Puerto Rican child born to mother with inhalant allergy and/or asthma. Child not intubated at birth.	Home w/electricity Defined area in Balt 6-12 years Phys-diag asthma Current symptoms or medication in prev 3 mos	4-12 years (low-income) phys. diag. asthma Reside in King County, persistent asthma at time of recruitment
Outcomes	Asthma symptoms, medications, health care use	Asthma symptoms, Juniper QoL,	Asthma symptoms, health care use	Asthma symptoms, health care use	Asthma symptoms, medications, health care use, Child behavior	SPT, IgE, dust levels, symptoms, ER visits	Respiratory symptoms, PFT, medications, health care use	Asthma symptoms, medications, health care use, FEV_1	Asthma symptoms, medications, health care use, FEV1 (HH2 only), QoL
Interventions									
Professional IPM	Yes	Yes	No	No	No	Yes	No	Yes	No
Reduce water intrusion	Yes	No	Yes	Yes	No	No	No	No	No (assessed for

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									intrusion and made recommendations but did not remediate)
Remove mold	No	No	Yes	Yes	No	No	No	No	No (not professionally, but taught how to wash mold from walls)
Provide portable air cleaner	No	No	No	No	Yes (2 in each home)	No	No	Yes	No
Prepare HH Action plan	No	No	No	No	No	Yes	No	No	Yes
Provide home-based education	Yes	Yes	Yes	Yes	Yes (smoking cessation)	Yes	No	Yes	Yes
Provide allergen-impermeable bed covers (mattress, box spring, pillows)	Yes	No	Yes	Yes	No	No	No	Yes	Yes
Provide vacuum cleaner	Yes (incl HEPA filter)	No	Yes	Yes	No	No	No	No	Yes
Conduct professional house cleaning	Yes	Yes	Yes	Yes	No	Yes	No	No	No
Replace mattress	No	Yes	No	No	No	No	No	No	No
Provide air conditioner	Yes	No	No	No	No	No	No	No	No

Table 2: Home Evaluation Methods									
Name of Study	**Boston HH Partnership (Boston)**	**Boston Healthy Public Housing Initiative (Harvard)**	**Urban Mold & Moisture Prog. Composite (Cleveland Composite)**	**Urban Mold & Moisture Prog. Asthma Study (Cleveland Asthma)**	**Cincinnati Asthma Prevention Study (Cincinnati)**	**Reducing Indoor Allergen Exposures in Northern Manhattan and the South Bronx (Columbia IPM)**	**Socio-Cultural Influences on Allergic Sensitization (Columbia Birth Cohort)**	**Childhood Asthma in the Urban Environment (Hopkins)**	**Seattle-King Co. Healthy Homes 1 & Healthy Homes 2**
Home Evaluation									
Visual Assessment/Inspection Checklist	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	HH1: Yes HH2: Yes
Questionnaire/Resident Interview	Yes	No	Yes	Yes	No	Yes	Yes	Yes	HH1: Yes HH2: Yes
Age of House	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes
Type of House	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	HH1: No HH2: Yes
Location of House (rural vs. urban)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Building Condition	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Rodents	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Cockroaches	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mold	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes
Pets	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wall Moisture	Yes	Yes (leaks)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Peeling Paint	Yes	No	Yes	Yes	No	No	No	Yes	Yes
Water Damage	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes
Pest Control Use/Strategies	Yes	Yes	No	No	No	Yes	Yes	No	Yes
Type of heating system	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cleanliness of home	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Cleaning habits	Yes	No	No	No	No	Yes	Yes	No	Yes
Food debris/storage behaviors	No	Yes	No	No	No	Yes	No	Yes	Yes
Smoking in the house	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Environmental Sampling and Analysis									
Settled Dust Samples									
Allergen	Yes Mighty Mite; type of filter/sleeve not specified	Yes Mighty Mite w/filter collection device	Yes Mighty Mite w/Hysurf insert	Yes Mighty Mite w/Hysurf insert	Yes HVS-3 (dirt devil vacuum cleaner +cyclone collection device)	Yes; Mighty Mite w/filter collection device	Yes: Mighty Mite w/filter collection device	Yes: Standard portable vacuum w/unwoven fabric sleeve	HH1: Yes: HVS-3 (cyclone collection device); HH2: Yes: HVS-4
Kitchen	No	Floor	No	No	No	Floor, (4 min)	No	Floor: Entire floor	HH1: Floor HH2: No
Child's Bedroom	Floor: 2-1m^2 integrated samples	Bedding: materials and time unspecified	Floor: Adjacent to and beneath child's bed; "S" pattern in two directions over sampled area	Floor: Adjacent to and beneath child's bed; "S" pattern in two directions over sampled area	Floor: Center of room in high traffic area; 1 m^2 (3 min). Used a template; overlapping	Floor: 2 m^2 (4 min) Bedding: Pillows, upper half of bed (4 min)	(Mom's bedroom) Floor: 2 m^2 (4 min) Bedding: Pillows, upper half of bed (4 min)	Floor: 1 m^2 near & under bed (2 min) Bedding: mattress &	Floor: HH1: 1 m^2 or larger HH2: 4 x 0.25m^2 areas Living area sampled

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Name of Study	**Boston HH Partnership (Boston)**	**Boston Healthy Public Housing Initiative (Harvard)**	**Urban Mold & Moisture Prog. Composite (Cleveland Composite)**	**Urban Mold & Moisture Prog. Asthma Study (Cleveland Asthma)**	**Cincinnati Asthma Prevention Study (Cincinnati)**	**Reducing Indoor Allergen Exposures in Northern Manhattan and the South Bronx (Columbia IPM)**	**Socio-Cultural Influences on Allergic Sensitization (Columbia Birth Cohort)**	**Childhood Asthma in the Urban Environment (Hopkins)**	**Seattle-King Co. Healthy Homes 1 & Healthy Homes 2**
			Carpeted Floor: (2 min) up to 2 - 3 m^2 Bare Floor: Entire floor + base of each wall (1 min)	Carpeted Floor: 0.25 m^2 (2 min) up to 2 - 3 m^2 Bare Floor: Entire floor + base of each wall (1 min)	passes but vacuumed each floor area once.			bedding (2 min) (combined w/ floor)	instead if that is where the child sleeps
Living Room/Main Activity Room	No	No	Floor: Middle of LR; up to 2-3 m^2 (2 min)	Floor: Middle of LR; up to 2-3 m^2 (2 min)	Floor: 1 m^2 (3 min)	Floor+sofa or chair: 2 m^2 (4 min)	No	Std methods (Platts-Mills et al (1992))	Floor: HH1: 1 m^2 or larger HH2: 4 x 0.25m^2 areas
Allergen Analysis	50 ug sieved dust (40-mesh screen) Dust shipped to lab on ice Dust stored at -20 C Extract stored at -20 C ELISA	100 mg sieved dust (425 um screen) Dust stored at -20C Extract stored at -20C ELISA	200 mg sieved dust (300-micron screen) Dust shipped to lab at ambient temp Dust stored at 4 C Extract stored at -20 C ELISA	200 mg sieved dust (300-micron screen) Dust shipped to lab at ambient temp Dust stored at 4 C Extract stored at -20 C ELISA	60 mg sieved dust (45 mesh screen) Dust not shipped Dust stored at -20 C Extract stored at -20 C ELISA	No sieving Dust not shipped Dust stored at -20 C Extract stored at -20 C ELISA	No sieving Dust not shipped Dust stored at -20 C Extract stored at -20 C ELISA	100 mg sieved dust (300 um sieve size) Dust not shipped Dust stored at -30 to -20 C Extract stored at -30 C ELISA	100 mg sieved dust (150 um sieve size) Dust shipped to lab on ice Dust stored at 4 C Extract stored at -20C ELISA
Units for Allergen Analyses	Concentration	Concentration	Concentration and loading	Concentration and loading	Concentration	Concentration	Concentration	Concentration & loading	Concentration & loading
Dust mite	Bedroom: Der f1, Der p1 Units: ng/g	Bedroom: Der f1, der p1 Units: ug/g	Bedroom: Der f1, der p1 Units: ug/g	Bedroom: Der f1, der p1 Units: ug/g	Bedroom: Der f1 Units: ug/g	Bedroom: Der f1 Units: ug/g	Bedroom: Der f1; der p1 Units: ug/g	Bedroom & Kitchen: Der f1, der p1 Units: ng/g	HH1: Bedroom: der f1; der p1 Units: ug/g HH2: Bedroom: Der p1 Units: ng/g
Cockroach	Bedroom: Bla g1; Bla g2 Units: U/g	Bedroom, Kitchen: Bla g1; bla g2 Units: U/g	Bedroom: Bla g1 Units: U/g	Bedroom: Bla g1 Units: U/g	Bedroom: Bla g1 Units: U/g	Bedroom, Kitchen: Bla g1; Bla g2 Units: U/g	Bedroom: Bla g 2 Units: U/g	Bedroom, Kitchen: Bla g1 Units: U/g	HH1: Bedroom: None; Kitchen: Bla g2 Units: ng/g HH2: None
Pets	Bedroom: Fel d1; Can f1	Bedroom: Fel d1; can f1	No	No	Bedroom: Fel d1; can f1	No	Bedroom: Fel d1 Units: ug/g	Bedroom, Kitchen: Fel d1,	HH1: Bedroom: Fel d1, can f1

Table 2: Home Evaluation Methods									
Name of Study	**Boston HH Partnership (Boston)**	**Boston Healthy Public Housing Initiative (Harvard)**	**Urban Mold & Moisture Prog. Composite (Cleveland Composite)**	**Urban Mold & Moisture Prog. Asthma Study (Cleveland Asthma)**	**Cincinnati Asthma Prevention Study (Cincinnati)**	**Reducing Indoor Allergen Exposures in Northern Manhattan and the South Bronx (Columbia IPM)**	**Socio-Cultural Influences on Allergic Sensitization (Columbia Birth Cohort)**	**Childhood Asthma in the Urban Environment (Hopkins)**	**Seattle-King Co. Healthy Homes 1 & Healthy Homes 2**
	Units: ng/g	Units: U/g			Units: ug/g			can f1 Units: ng/g	Units: ug/g HH2: fel d1 Units: ng/g
Mouse	Bedroom: Mup[b] Units: ng/g	Bedroom, Kitchen: Mup[b] Units: ug/g	Bedroom: Mus m1 Units: ng/g	Bedroom: Mus m1 Units: ng/g	Bedroom: No	Bedroom, Kitchen: Mup[b] (ug/g)	Bedroom: Mup[b] (ug/g)	Bedroom, Kitchen: Mus m1 (ng/g)	HH1: No HH2: No
Rat	No	No	Bedroom: Rat n1	Bedroom: Rat n1	No	No	No	No	No

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Endotoxin in dust	No	No	Yes	Yes	No	No	No	No	No
Pesticides in dust	No	Yes (wipes)[a]	No	No	Yes	No	No	Yes	No
Mycotoxin in dust	No	No	No	No	No	No	No	No	No
B-glucan in dust	No	No	Yes	Yes	No	No	No	No	No
Mold in dust	No	Yes: culture (alternaria)	Yes: culture & PCR (33 species/groups; viable and non-viable)	Yes: culture & PCR (33 species/groups; viable and non-viable)	No	No	No	No	HH1: No HH2: ergosterol as fungal biomarker
Air Samples									
Endotoxin in air	No	No	No	No	No	No	No	No	No
Particulate in air	Yes (PM10)	No	No	No	Yes: GT-321 particulate monitor 1 minute real-time measurement at 0.3 um and 5 um; child's BR, K, LR, and outdoors	No	No	Yes (PM10 & PM2.5; 3-day samples; 4 Lpm MSP impactors loaded w/37-mm 2.0-um pore size PALL Teflon PTFE membrane filters w/polypropylene support rings. Also, Time-resolved PM using portable direct-reading nephelometer with data logging capabilities (MIEpDR100s)	No
Temperature and humidity	Yes (real-time, outside only)	Yes (14-day, inside only)	No	No	Real-time gauge, one-time measurement in child's BR, K, LR.	No	No	No	Yes (temperature only, real-time)
Mold in air	No	No	No	No	No	No	No	No	No

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Nitrogen dioxide	Yes	Yes	No	No	No	No	No	Yes (3-day Ogawa passive sampler in child's BR)	No
Ozone	No	No	No	No	No	No	No	Yes (3-day Ogawa passive sampler in child's BR)	No
Nicotine	No	No	No	No	Yes (6 month dosimeter)	No	No	No	No
Allergens	No	Yes (bla g1, bla g2, MUP, der f1, der p1, fel d1, can f1, fungal)	No	No	No	Yes (bla g2, MUP 1)	No	Yes	No
Other types of Samples									
Surface moisture	No	No	Yes (areas w/signs of moisture damage) Delmhorst BD-2100	Yes (areas w/signs of moisture damage) Delmhorst BD-2100	No	No	No	Yes (4 walls+ceilings)	No

[a]2 organophosphates and 11 pyrethroids
[b]For the purposes of this study, MUP results were converted to mus m1 by mus m1=0.67xMUP (Chew et al., 2005)

Table 3: Health Assessment Methodologies									
Name of Study	**Boston HH Partnership (Boston)**	**Boston Healthy Public Housing Initiative (Harvard)**	**Urban Mold & Moisture Prog. Composite (Cleveland Composite)**	**Urban Mold & Moisture Prog. Asthma Study (Cleveland Asthma)**	**Cincinnati Asthma Prevention Study (Cincinnati)**	**Reducing Indoor Allergen Exposures in Northern Manhattan and the South Bronx (Columbia IPM)**	**Socio-Cultural Influences on Allergic Sensitization (Columbia Birth Cohort)**	**Childhood Asthma in the Urban Environment (Hopkins)**	**Seattle-King Co. Healthy Homes 1 & Healthy Homes 2**
Health Survey	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
NCICAS	Yes	No	No	No	No	No	No	Yes	No
NAEPP	No	No	No	No	No	No	No	No	Yes
AAP Children's Health Survey for Asthma	No	No	Yes	Yes	Yes	No	No	No	No
Quality of Life Survey	No	Yes (Juniper)	Yes[a]	Yes[a]	Yes[a]	No	No	Yes	Yes (Juniper)
Family Demographics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Asthma Disease Activity									
Day symptoms	Yes	Yes	Yes	Yes	Yes	Yes	NA	Yes	Yes
Night symptoms	Yes	Yes	Yes	Yes	Yes	Yes	NA	Yes	Yes
Exercise symptoms	Yes	Yes	Yes	Yes	Yes	No	NA	Yes	Yes
Limits in Activity	Yes	Yes	Yes	Yes	Yes	Yes	NA	Yes	Yes
Days of School Missed	Yes	No	Yes	Yes	Yes	Yes	NA	No	Yes
Preventive Medication	Yes	Yes	Yes	Yes	No	Yes	NA	Yes	Yes
Rescue Medication	Yes	Yes	Yes	Yes	No	Yes	NA	Yes	Yes
Emergency Dept. Visits	Yes	No	Yes	Yes	Yes	Yes	NA	Yes	Yes
Hospitalization	Yes	Yes	Yes	Yes	Yes	Yes	NA	Yes	Yes
Allergy history	NA	Yes	Yes	Yes	Yes	Yes	NA	Yes	Yes
Family History	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Clinical Tests									
Nasal Wash (leukocytes/fungi)	No	No	Yes	Yes	No	No	No	No	No
Pulmonary function test (FEV1)	No	Yes	Yes	Yes	Yes	No	NA	Yes	HH1: No HH2: Yes
Expired NO_2	No	No	No	No	Yes	No	No	No	No
Urine test	No	No	No	Yes (see cotinine)	Yes	No	No	Yes	No
Skin test[d]	No	Yes (German cockroach, der f1, der p1, mouse epithelia, cat hair, dog hair and dander, 3	No	No	No	Yes (German cockroach, mouse urinary protein, der f)	No	Yes (German cockroach, American cockroach; mix of der f1/der p1, rat, mouse	HH1and HH2: Yes (German cockroach, der f1, der p1, rat, mouse, cat, dog, 4 molds, 3 tree pollen)

Table 3: Health Assessment Methodologies									
Name of Study	**Boston HH Partnership (Boston)**	**Boston Healthy Public Housing Initiative (Harvard)**	**Urban Mold & Moisture Prog. Composite (Cleveland Composite)**	**Urban Mold & Moisture Prog. Asthma Study (Cleveland Asthma)**	**Cincinnati Asthma Prevention Study (Cincinnati)**	**Reducing Indoor Allergen Exposures in Northern Manhattan and the South Bronx (Columbia IPM)**	**Socio-Cultural Influences on Allergic Sensitization (Columbia Birth Cohort)**	**Childhood Asthma in the Urban Environment (Hopkins)**	**Seattle-King Co. Healthy Homes 1 & Healthy Homes 2**
		molds, ragweed pollen mix, 11 tree mix, 7 grass mix, cladosporium))						epithelia, cat hair, dog hair and dander, 3 molds, ragweed pollen mix, helminthosporium, grass pollen, tree pollen)	
Total IgE[b,c]	No	No	Yes	No	No	Yes	No	No	No
RAST (Serum Allergen Specific IgE)[c]	Yes (max of either der f1or der p1); cat dander and epithelium; max of either dog dander or dog epithelium; cockroach; mouse epithelium; 4 molds	No	Yes (der p1, cockroach, baseline mouse urinary proteins, rat urine, mold (10 species))	Yes (der p1, cockroach, baseline mouse urinary proteins, rat urine, mold (10 species))	Yes (der f1, cat dander and epithelium, dog dander, cockroach)	Yes (cockroach, baseline mouse urinary proteins)	No	No	No
Eosinophil count	No	No	Yes	Yes	No	No	No	[?]	No
Cotinine	No	No	No	Yes (urinary)	Yes (Serum/hair)	No	No	[?]	No

[a]The AAP Children's Health Survey for Asthma includes quality-of-life questions; therefore, grantees who said that they conducted this survey were listed as "yes" for the quality-of-life survey.
[b]Total IgE is a marker of all of the IgE antibodies that a person has in his/her serum; therefore, one cannot simply calculate the sum of each allergen-specific IgE to get total IgE.
[c]Serum IgE levels were considered positive if IgE greater than or equal to 0.35 IU/ml for specific allergens or when IgE greater than or equal to 100 IU/ml for total IgE.
[d]Skin test results were considered positive if greater than or equal to 3 mm above saline wheal size.