Housing-Related Determinants of Childhood Asthma Morbidity

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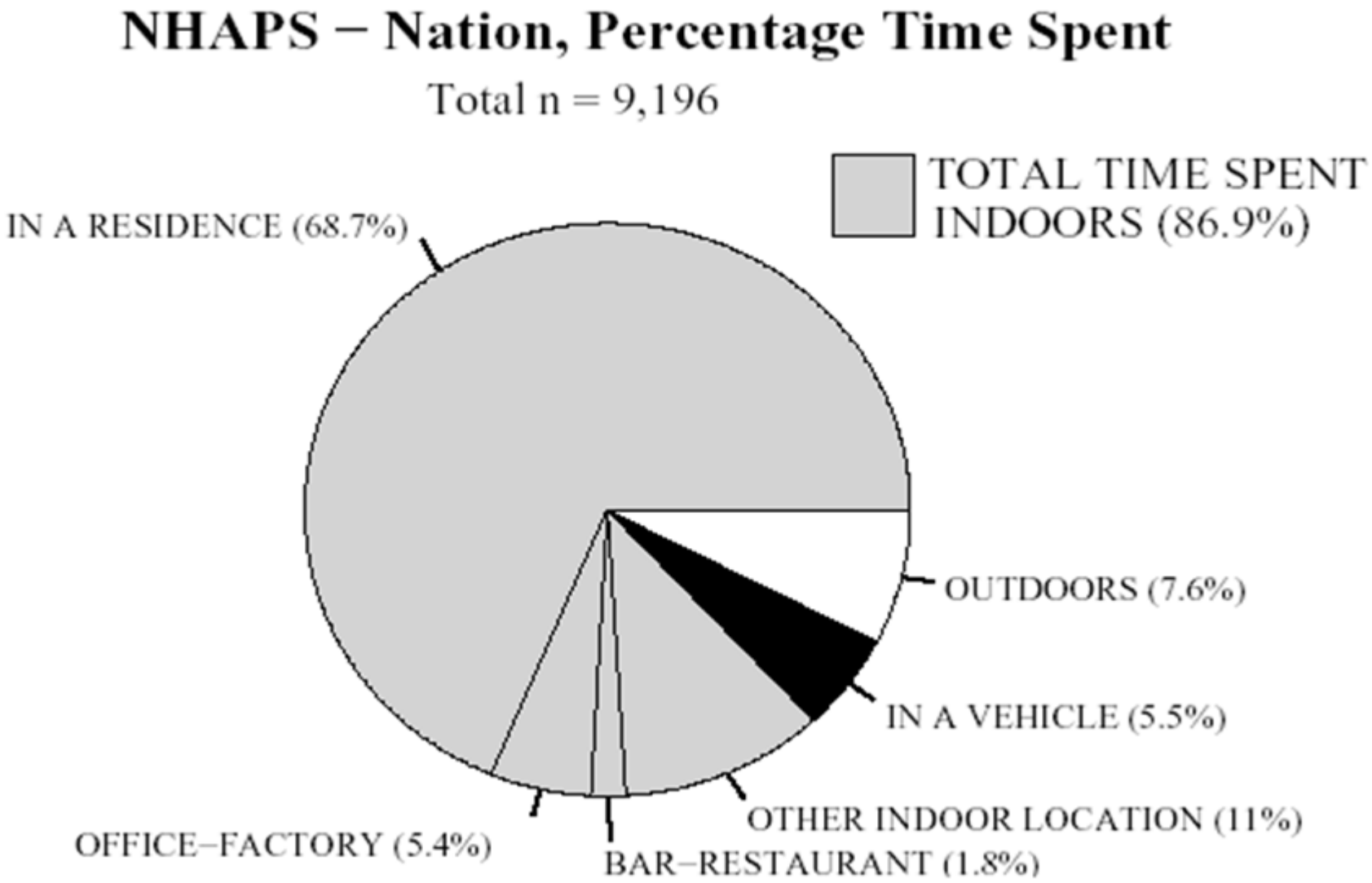
Environmental Exposures

- Road traffic is the main contributor to outdoor air pollution in urban areas
- In asthma, outdoor air pollution is associated with:
  - ED visits
  - increased symptoms
  - decreased lung function

Breysse et al. Environ. Res. 2005;98:167-76
D'Amato et al. Clin Exp Allergy 2005; 35:1113-24
Gilmour et al. EHP 2006; 114:627-33

National Human Activity Pattern Survey



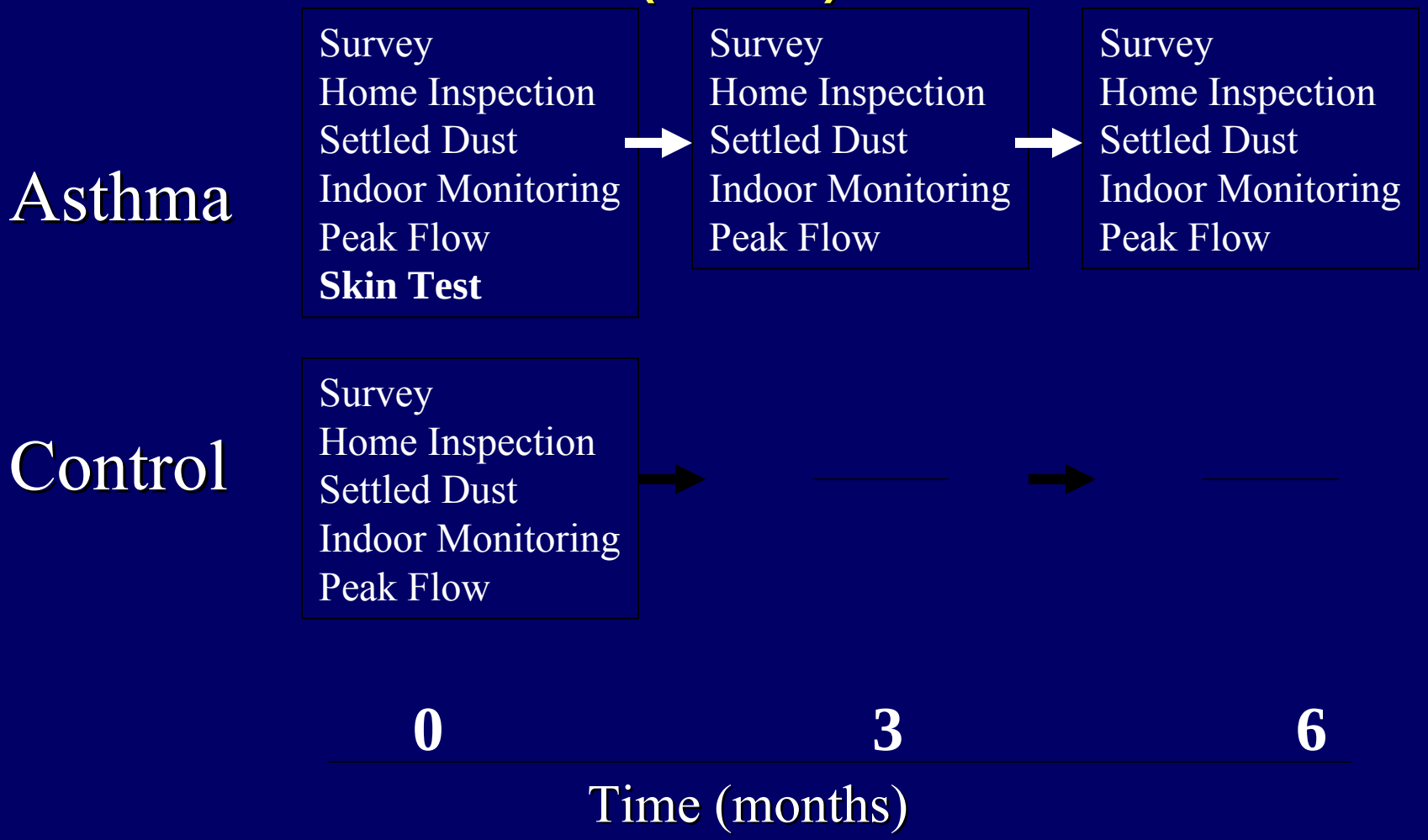
Indoor Exposures

- Indoor air pollutants are independently associated with increased asthma risk
- Quality of the indoor environment is directly related to housing quality.
- Inner city homes
  - More likely on arterial street
  - Old / in poor repair
  - Leaky roofs, water damage, mold contamination
  - CR and rodent infestation
  - High smoking rates
  - Gas stoves
  - Unvented appliances
  - High indoor NO_2 and PM level

Breysse et al. Environ. Res. 2005;98:167-76
Sharma et al. Pediatr Clin N Am. 2007; 54:103-20
Simons et al. J of Urban Health. 2007.

Study Design

Baltimore Indoor Environment Study of Asthma in Kids (BIESAK)



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Home Environmental Monitoring

3 day integrated air sample in subject's bedroom:

- PM_{10} impactor with pump (4 lpm)
- $PM_{2.5}$ impactor with pump (4 lpm)
- MIE pdR 1000AN
- Ogawa Ozone
- NO_2 sampler

- Home inspection (checklist)
- Wall moisture measures
- Settled dust
  - Kitchen, living room, bedroom
  - cockroach, dust mite, cat, dog, mouse allergens

Outcome Measures

- Symptoms in the past 2 weeks
  - Wheezing, coughing, or chest tightness
    - Daytime
    - Nighttime
  - Slow down or stop activities
  - Wheezing that limited child's speech
- Rescue medication use in past 2 weeks:
  - Short-acting beta agonist
- Lung function (PF)

Does indoor air differ between asthmatic and control homes?

	Asthma	Control	p
$PM_{2.5}$ (μg /m3)	28.7 (18-51)	28.5 (17-50)	0.99
PM_{10} (μg /m3)	43.7 (29-70)	41.1 (27-68)	0.35
Time-resolved PM			
Peak (μg /m3)	705 (310-1995)	780 (310-2110)	0.80
Daily (μg/m3)	20 (10-40)	20 (10-40)	0.93
NO_2 (ppb)	21.6 (14-34)	20.9 (14-31)	0.84
Ozone (ppb)	1.4 (0.9-3.4)	1.8 (0.9-4.1)	0.56

Diette et al. EHP. 2007

Nitrogen Dioxide (NO_2)

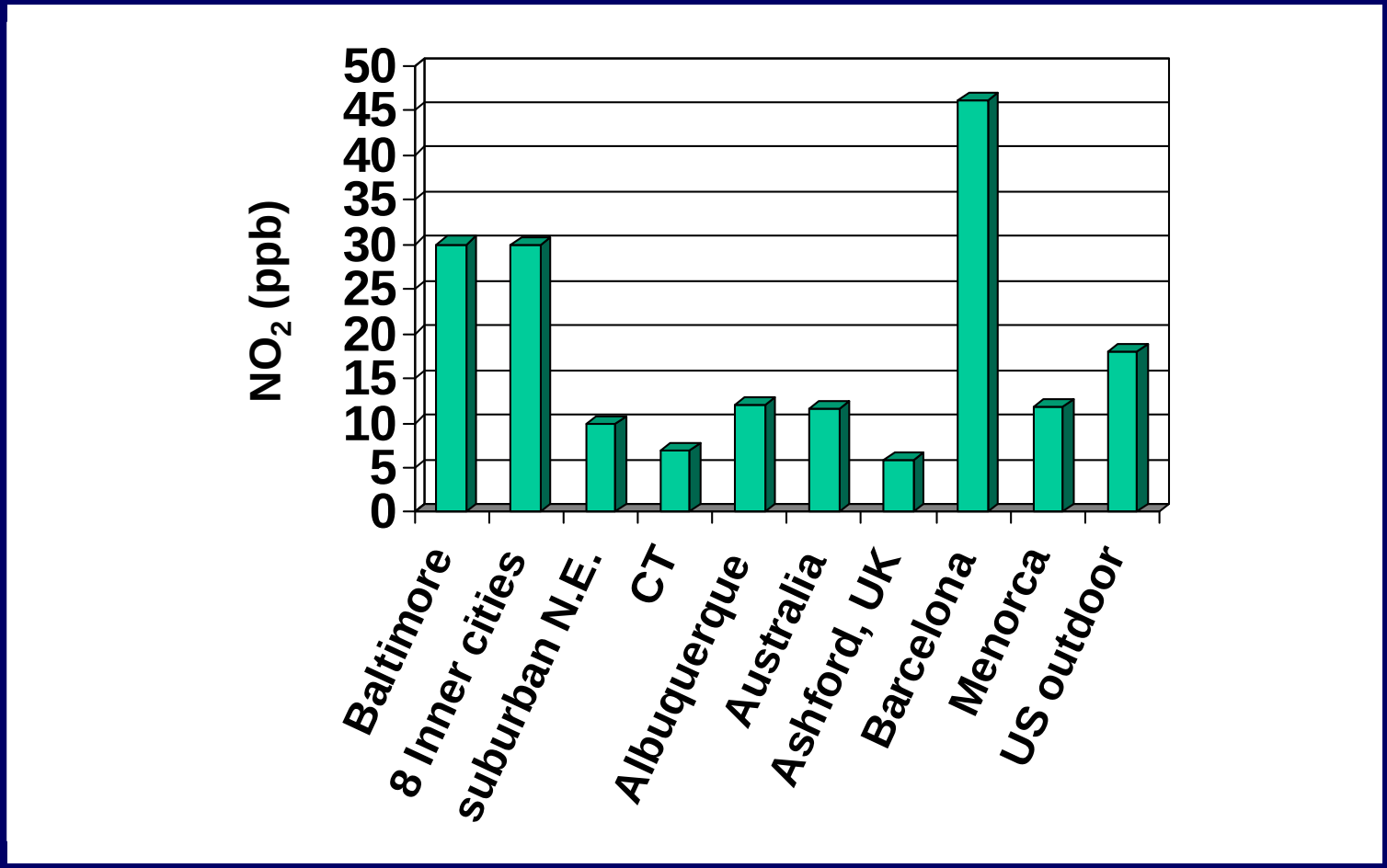
- Toxic free radical gas that is a component of air pollution
- Formed by the combustion of fossil fuels
- Outdoor sources - Emissions from motor vehicles, power plants, fossil fuel burning industries
- Indoor sources – kerosene heaters, gas cooking stoves, gas powered ice scrapers used in hockey rinks, tobacco smoke

NO_2 effects on the lungs and asthma

- May lead to increased asthma morbidity
  - Epithelial damage
    - Lipid peroxidation
    - Thiol oxidation
    - Formation of 3-nitrotyrosine
    - Activation of MAPK signaling pathway
  - Lowering threshold for viral-induced asthma exacerbations
  - Promotes allergic sensitization to inhaled antigen
- Limitations / unknown
  - Effect in inner city, where exposure may be high
  - effect in pre-school children
  - adjusting for other indoor pollutants

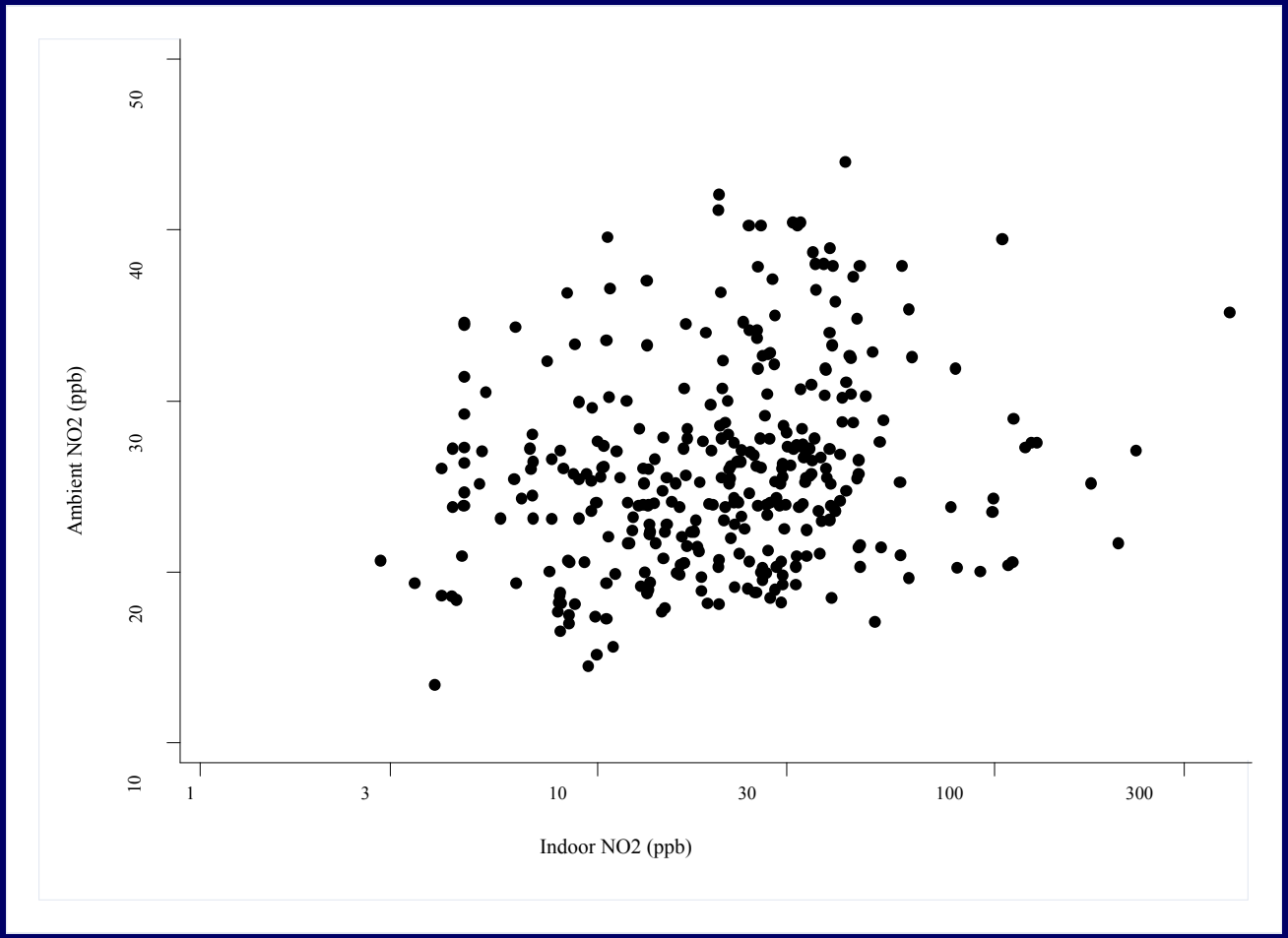
Persinger 2002
Chauhan
Bevelander et al. 2007

Indoor NO2 concentrations in inner city Baltimore homes



Sunyer. 2004, Van Strien. 2004, Kattan, 2007, Nitschke, 2006, Garrett, 1998.

Correlation with indoor and outdoor NO2



R^2 = 0.015, p=0.02

Indoor NO_2 sources

	%	Beta	P-val
Housing characteristics			
Gas stove	83	**15.0**	**<0.001**
Gas heater	72	7.2	0.05
Daily activities over the monitoring period			
Space heater use	5	**16.40**	**0.04**
Stove/oven for heat	12	**12.49**	**0.02**
Sweeping	85	1.00	0.08
Cigarettes	56	0.04	0.59
Open windows	85	-0.38	0.29
Candles/incense	32	-2.37	0.52
Air purifier use	1	-9.17	0.65

Hansel et al. EHP. In press

Risk of symptoms per 20 ppb increase in NO_2

	Unadjusted		Adjusted	
Symptom	**IRR**	**95% CI**	**IRR**	**95% CI**
Daytime wheezing, coughing or chest tightness	1.05	(0.99, 1.12)	1.03	(0.96, 1.11)
Slowing activity	1.07	(1.00, 1.14)	1.06	(0.99, 1.14)
Limited speech	1.12	(1.04, 1.21)	1.15	(1.05, 1.25)
Symptoms while running	1.08	(1.01, 1.15)	1.07	(0.99, 1.14)
Coughing without a cold	1.13	(1.06, 1.20)	1.10	(1.02, 1.18)
Nocturnal symptoms	1.11	(1.04, 1.18)	1.09	(1.02, 1.16)

Models are adjusted for $PM_{2.5}$; SHS; season; age, sex, race and mother's education level.

Hansel et al. EHP. In press

Modification of Indoor NO_2 sources

- Replacement of gas stove / heater with electric stove / heat
- Proper ventilation of gas appliances
- General home ventilation
- Reduce improper use of gas appliances (i.e., gas stove for heat)

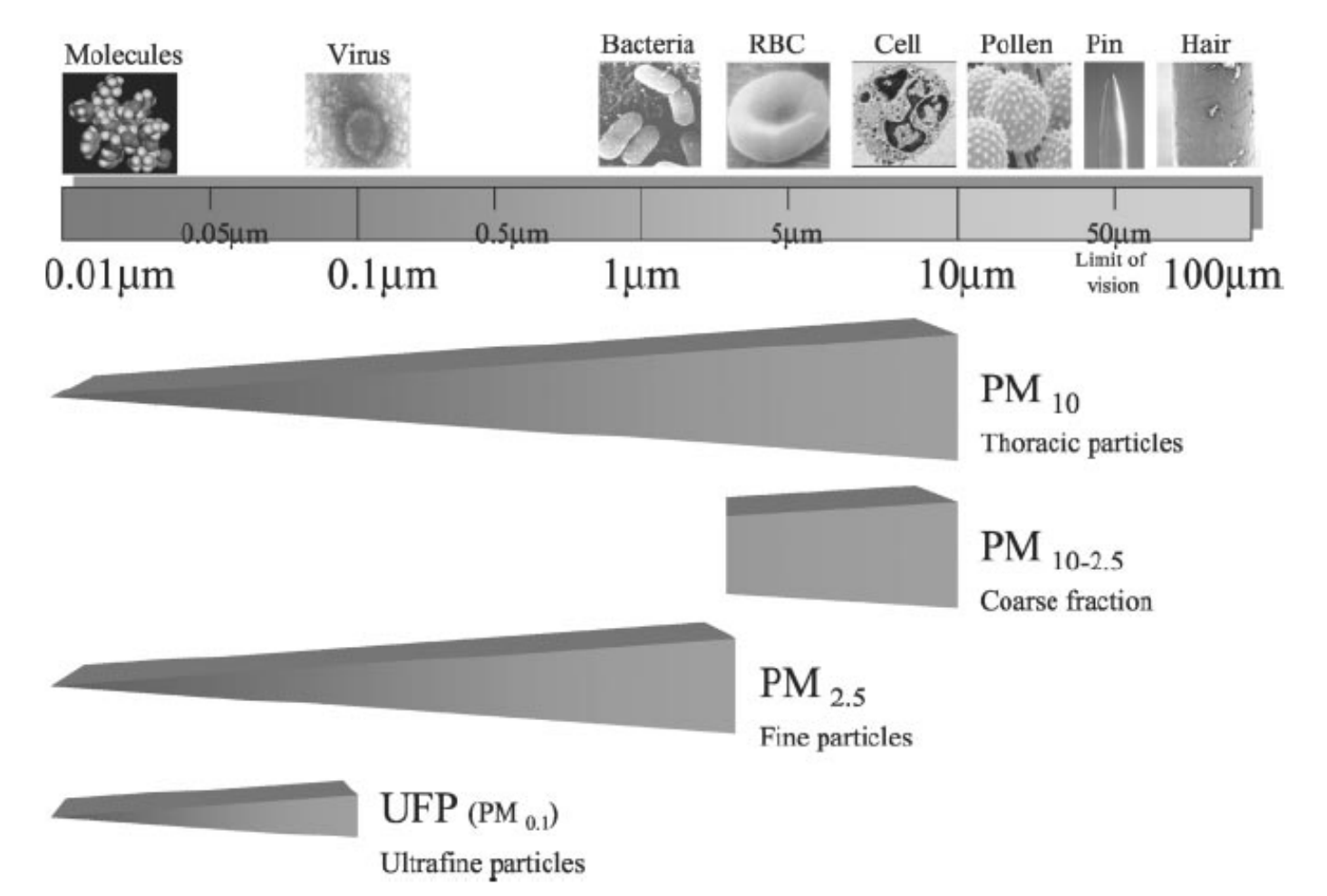
Airborne Particulate Matter

Natural Sources

- Earth's crust
- Forest Fires
- Pollen, spores
- Animal debris
- Bacteria, viruses

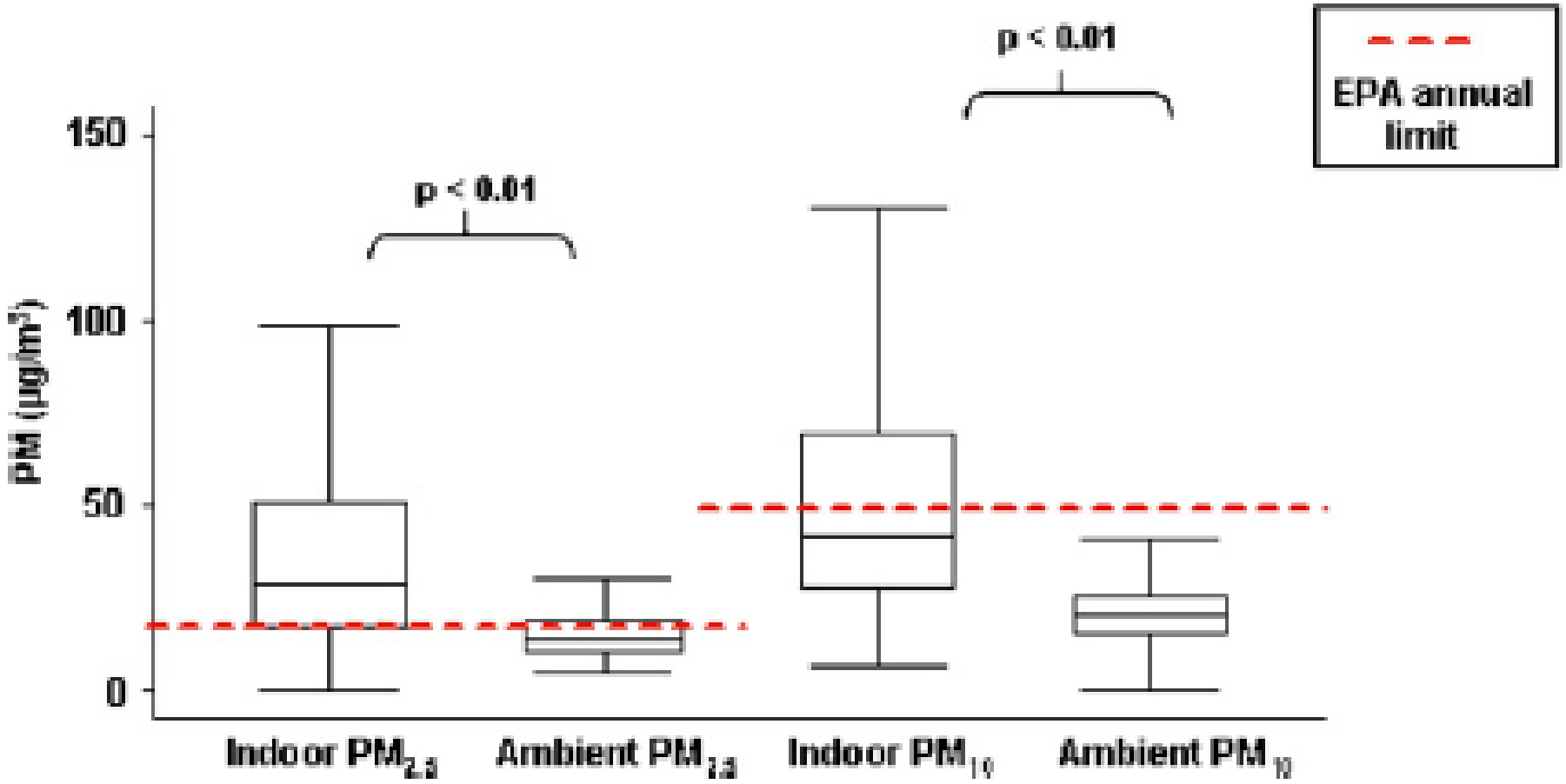
Man-made Sources

- Motor vehicles
- Factories
- Indoor Specific
  - Tobacco Smoke
  - Cooking fuels
  - Incense



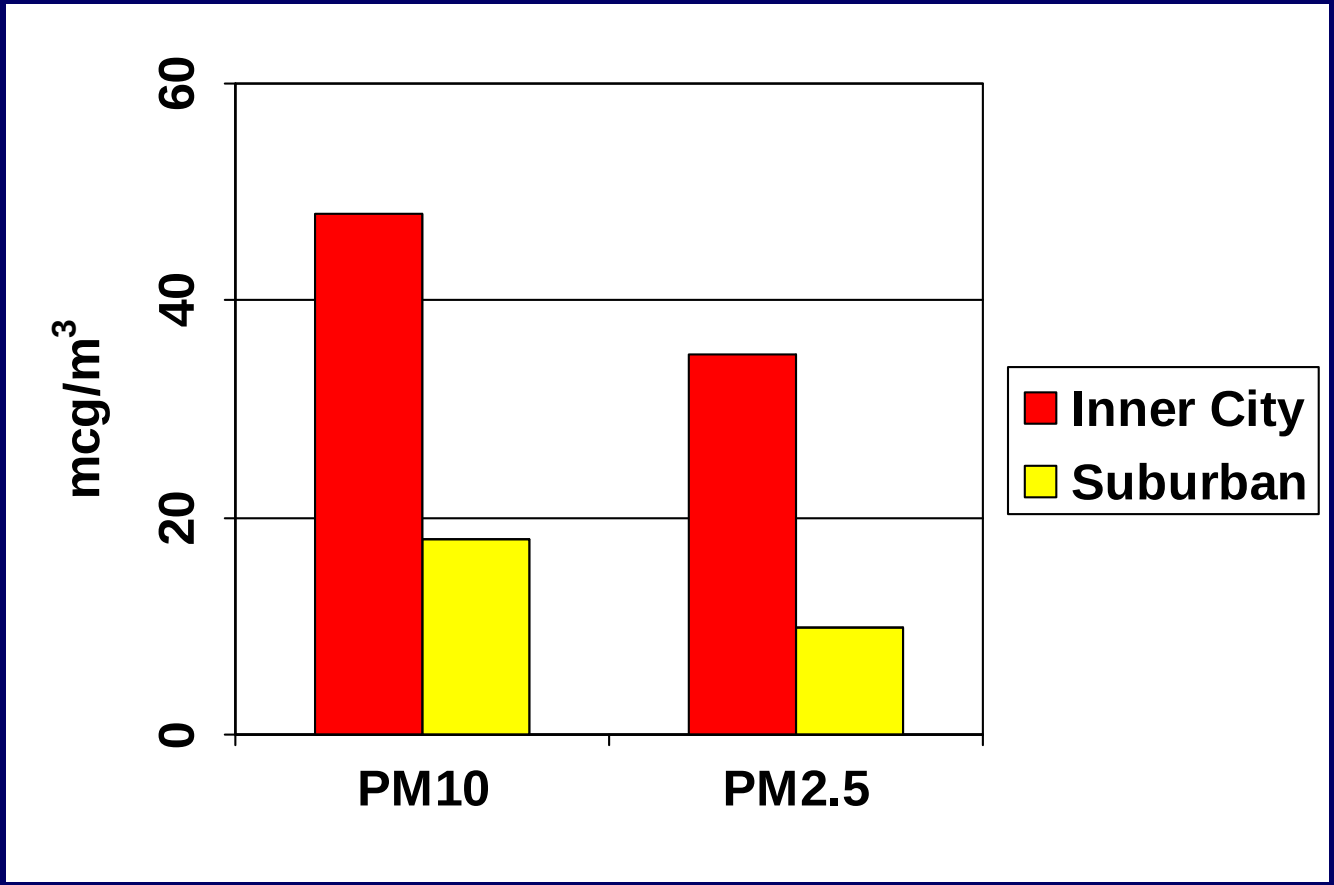
Brook RD Circulation 2004

PM levels in inner city Baltimore



McCormack et al . Env Res. 2007

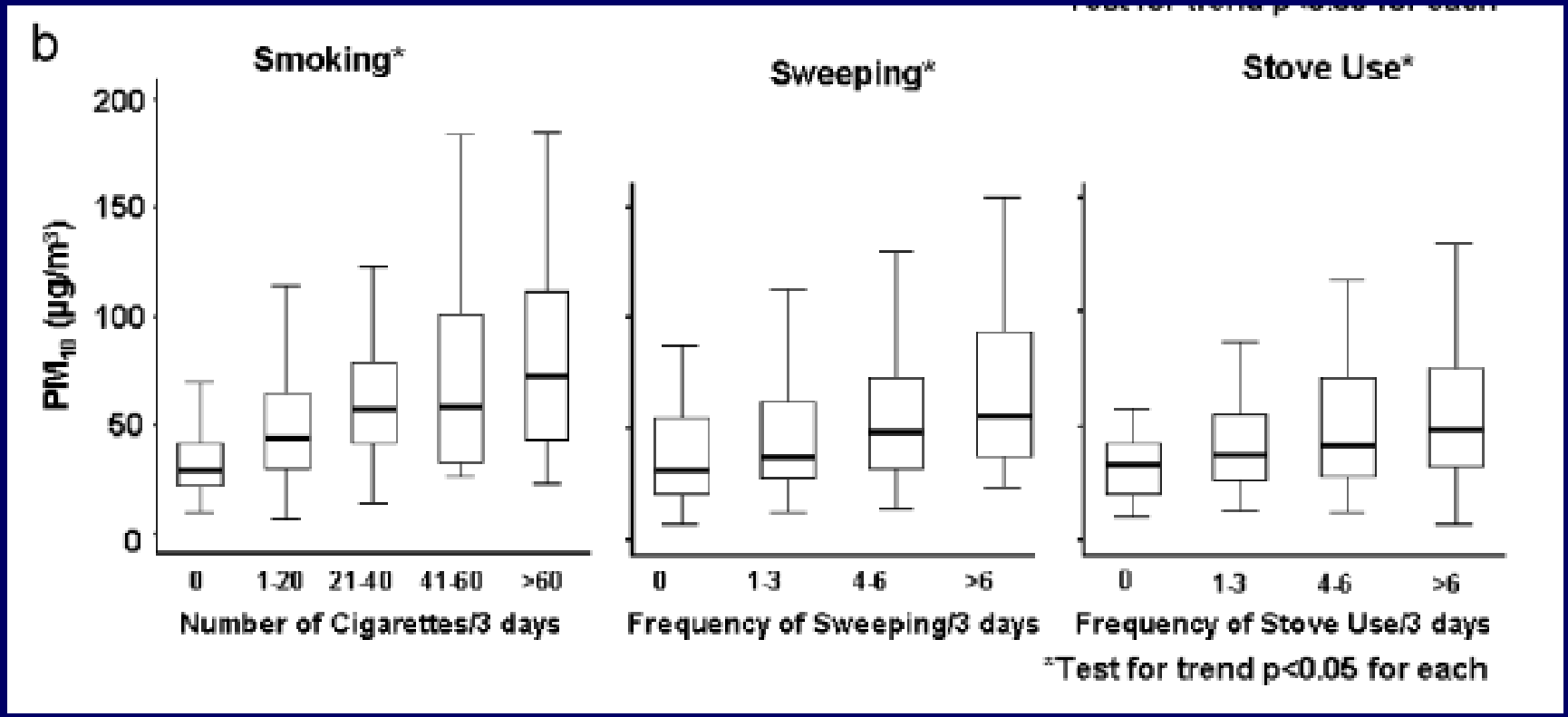
PM levels in inner city vs. suburban Baltimore Homes



P<0.001

Simons et al. 2007.

Indoor contributions to PM



- Open windows associated with lower PM concentrations
  - For each window open > 10 min/d, $PM_{2.5}$ was 0.88 µg/m^3 lower

McCormack et al . Env Res. 2007

Differential Health Effects of Particle Sizes

- Little previous investigation of relative effects of fine ($PM_{2.5}$) versus coarse (PM_{10}-$PM_{2.5}$) particulates
- Some evidence for effect of ambient coarse PM on mortality[1]
- Studies of asthma, COPD, respiratory disease suggest that ambient coarse PM has as strong or stronger association with short-term morbidity compared to fine PM[1]

[1]Brunekreef et al. ERJ 2005

Coarse Indoor PM Exposure and Respiratory Symptoms

Symptom Outcomes	Coarse PM (per 10 ug/m3)		
	IRR	95% CI	P-value
Cough/wheeze/ chest tightness	1.06	1.01, 1.12	0.02
Slow/stop activities	1.08	1.02, 1.14	0.01
Limited speech from wheeze	1.11	1.03, 1.19	<0.01
Nocturnal Symptoms	1.08	1.01, 1.14	0.01
Symptoms with running	1.00	0.94, 1.08	0.81
Rescue Medication Use	1.06	1.01, 1.10	0.02

*Adjusted for age, gender, race, parent education level, season, indoor fine PM, ambient fine PM, ambient course PM

Fine Indoor PM Exposure and Respiratory Symptoms

Symptom Outcomes	Fine PM (per 10 ug/m3)		
	IRR	95% CI	P-value
Cough/wheeze/ chest tightness	1.03	0.99, 1.07	0.18
Slow/stop activities	1.04	1.0, 1.09	0.06
Limited speech from wheeze	1.07	1.01, 1.14	0.04
Nocturnal Symptoms	1.5	0.98, 1.12	0.06
Symptoms with running	1.07	1.02, 1.11	<0.01
Rescue Medication use	1.04	1.01, 1.08	0.04

*Adjusted for age, gender, race, parent education level, season, indoor coarse PM, ambient coarse PM, ambient fine PM

Conclusions / Implications

- Homes of children in inner-city Baltimore have high indoor air pollution, particularly NO_2 and PM.
- Gas stove use, gas heater use, use stove/oven for heat and space heater use are associated with elevated NO_2 concentrations.
- Cigarette smoke, sweeping, stove use and open windows are associated with indoor PM concentrations.
- Elevated NO_2 and PM levels are independently associated with increased asthma symptoms
- The health of preschool inner-city children with asthma may be improved by reduction of indoor air pollutants. Intervention studies are needed.

Center for Childhood Asthma in the Urban Environment

Supported by NIEHS and EPA

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BUILDING A FRAMEWORK FOR HEALTHY HOUSING

2008 National Healthy Homes Conference

The New Orleans Healthy Home Project

Felicia Rabito, Elizabeth Holt, Kathy Lancaster

Tulane University
School of Public Health and Tropical Medicine

a global commitment to public health

Background

- Housing has been called the “ultimate nexus between the built environment and health.”
  - Residential hazards are associated with three leading causes of pediatric morbidity; elevated lead levels, asthma, and injury.

- Population exposure burden must be estimated before cohesive, integrated programs to mitigate health hazards can be developed.
  - Studies reveal significant regional variation in indoor allergen profile
  - These studies are not population-based

- NSLAH first population-based assessment of lead, allergens and endotoxin in U.S. homes.
  - Results indicated an interaction between region, income, humidity, moisture and allergen levels.
  - Cannot provide subpopulation estimates or estimates by geographic location

Objectives: N.O. Healthy Home Project

- To quantify allergen and lead levels in a population-based sample of homes in New Orleans, Louisiana.
- To explore regional differences in home allergen levels by comparing data from The National Survey of Lead and Allergen in Housing (NSLAH).
- To identify environmental conditions and socio-demographic variables associated with increased allergen and lead levels.
- To explore the relationships between allergen levels and the presence of asthma and allergies.

Study Design

- 3 year cross-sectional study of residential-based health and environmental hazards.

Recruitment and Sampling Frame

- Sampling frame: New Orleans Sewer and Water Board records.
- Sample Size: 109 homes stratified by Planning District.
- The number of homes selected for sampling from each Planning District was proportional to population estimates in each district.
  - based on population estimates from the Summer 2006 Rapid Population Estimate Survey and 2000 New Orleans census data.

Recruitment and Sampling Frame

- From this sampling frame, households were recruited by:

(1) Drive-bys (Door knocking)

- Technicians determine the occupancy of the houses.
- If technicians believe the house to be occupied or they are unsure about the occupancy, then they will knock on the door to make contact.
- If contact is made, the technicians will speak with the client. If contact is not made, the technicians will leave the recruitment materials.

(2) Two follow up letters

(3) Revisiting houses thought to be occupied

Occupancy (circle one)
1- Unoccupied
2-Unsure/Unocc.
3-Unsure
4-Unsure/Occ.
5-Occupied
6-No address
7-Business

Recruitment and Sampling Frame

- Eligibility Criteria
  - Primary residence defined as the place where participant spends 4 or more nights per week.
  - FEMA trailers excluded.

Data Collection

- Residential survey
  - Visual observation
  - Resident questionnaire

- Environmental measurements
  - Mold (air and dust samples)
  - Temperature
  - Dew point and relative humidity
  - Indoor dust allergens (dust mites, cat dander, cockroach, mouse)
  - Dust endotoxin
  - NO_2 levels
  - Lead (dust and soil)

Survey Methods

- **Visual Observation Form**
  - Technicians assess the home for presence of:
    - Visible mold, mildew, any biological growth
    - Visible moisture, or water damage caused by flooding or leakage
    - Pets in the house
    - Evidence of environmental tobacco smoke
    - Evidence of cockroaches and rodents
    - Upholstery, floor coverings, and window treatments
    - Gas cooking appliances

- **Residential Questionnaire**
  - Interviewer-administered face to face survey questionnaire
    - Housing type, demographics, indoor environment, effects of Hurricane Katrina, flooding and remediation activities.
    - Household members' atopy, respiratory symptoms, and perceived stress.

Environmental Measurements*

- Mold (air)
  - Outdoor samples: (Aircheck® 2000 pump with 2 µm pore size Teflon filter, 3l/minute flow rate) ran for 60 minutes.
  - Indoor samples: overnight (minimum = 8 hours) in bedroom and common living area. Samples were analyzed for air mold cultures with speciation and PCR analysis.
- Allergens and Mold (dust)
  - Vacuum sampling used to collect a 2 square yard sample from common living area and master bedroom floors (composite sample).
  - Vacuum bag sample in homes with a vacuum cleaner.
- Humidity and Temperature
  - Direct readings in common living area, bedroom and the kitchen.
  - HOBO data logger logged continuous measurements for one week (common living area and bedroom).
- Lead
  - Dust wipe samples from the windowsills and floors of kitchen, bedroom and common living area. One soil sample was taken from the entrance area in front of the home.

*All sampling protocols adapted from current HUD / EPA protocols

Study Results

(n=109 Households)

Sampling Period: January 2007 - August 2008

Recruitment and Sampling Frame

- Sample size per Planning District

Planning District (Number)	House to be enrolled	# enrolled
French Quarter/CBD (1)	5	3
Garden District/Central City (2)	20	17
Uptown/Carrolton (3)	26	27
Mid city (4)	11	14
Lakeview (5)	3	12
Gentilly (6)	3	9
Bywater (7)	6	6
Lower 9th (8)	1	0
New Orleans East (9)	1	11
Algiers (12)	24	10
Total Sample Size	**100**	**109**

I. Household Characteristics

I. Household Characteristics

Characteristic	n(%)
Household Income	
<$30,000/year	24(22.0)
$30,000 - $60,000	17(15.6)
>$60,000	40(36.7)
Don't Know / Refused	29(26.6)
Race / Ethnicity	
% Caucasian	67(61.5)
% African-American	41(37.6)
1+children living in the home	53(48.6)
Year house was built	
1978 to present	13(11.9)
1940 to 1977	36(33.0)
Before 1940	53(48.6)

I. Household Characteristics (cont'd)

Characteristic	n(%)
Hurricane Katrina Flooding	
No floodwater in the house	62(56.9)
Less than 1 inch	4(3.7)
1 to 6 inches	5(4.6)
6 inches to 1 foot	4(3.7)
2 to 5 feet	19(17.4)
Greater than 5 feet	14(12.8)
Renovation Status at time of Sampling	
Renovations are complete	43(39.8)
House currently under renovation	31(28.7)
House needs renovations but not yet started	13(12.0)
House did not need renovation	19(17.6)
Home Ownership	
Own	30(75.0)
Rent	10(25.0)

II. Indoor and Outdoor Lead Levels

II. Indoor and Outdoor Lead Levels

Sampling Area	n(%)
Kitchen Floor (n=109)	
>40 ug/ft ^{2*}	16(14.7)
Kitchen Windowsill (n=102)	
>250 ug/ft ^{2*}	23(15.7)
Bedroom Floor (n=75)	
>40 ug/ft ^{2*}	10(13.5)
Bedroom Windowsill (n=102)	
>250 ug/ft ^{2*}	30(29.4)
Living Room Floor (n=108)	
>250 ug/ft ^{2*}	13(12.5)
Living Room Windowsill	27(24.7)
>250 ug/ft ^{2*}	
Soil (n=89)	
>400 ppm†	42(47.2)
>1200 ppm††	24(27.0)

*federal lead guidelines for leaded dust clearance levels: wipe sampling

† federal lead guideline for lead in child's play areas

†† federal lead guideline for lead in yard area

II. Characteristics Associated With Elevated Soil Lead Levels (>400 ppm)

Year house was built	≤400ppm n(%)	>400ppm n(%)
1990 to present	6(12.8)	0(0.0)
Between 1978 and 1989	8(17.0)	0(0.0)
Between 1960 and 1977	12(25.5)	0(0.0)
Between 1946 and 1959	5(10.6)	0(0.0)
Between 1940 and 1945	2(4.3)	9(21.4)
1939 or before	14(29.8)	33(78.5)

p<0.0001 Cochran-Armitage test for trend

II. Characteristics Associated With Elevated Soil Lead Levels (>400 ppm)

Characteristics	<400ppm Pb n(%)	>400ppm Pb n(%)	p-value*
House built pre-1946	16(34)	41(97.6)	<0.0001
Concerned about the health impact of bare soil	25(73.5)	18(78.3)	0.6839
Owns Home	36(76.6)	25(59.5)	0.0834
Rent paid for by government housing program	2(14.3)	2(9.1)	0.6287
African-American resident	18(38.3)	13(31.0)	0.4678
Income			
<$30,000/year	8(25)	10(30.3)	0.448**
$30,000-$60,000/year	6(56.3)	8(24.3)	
>$60,000/year	18(56.3)	15(45.5)	

*p-value for Chi-Square test of association

** Cochran-Armitage test for trend

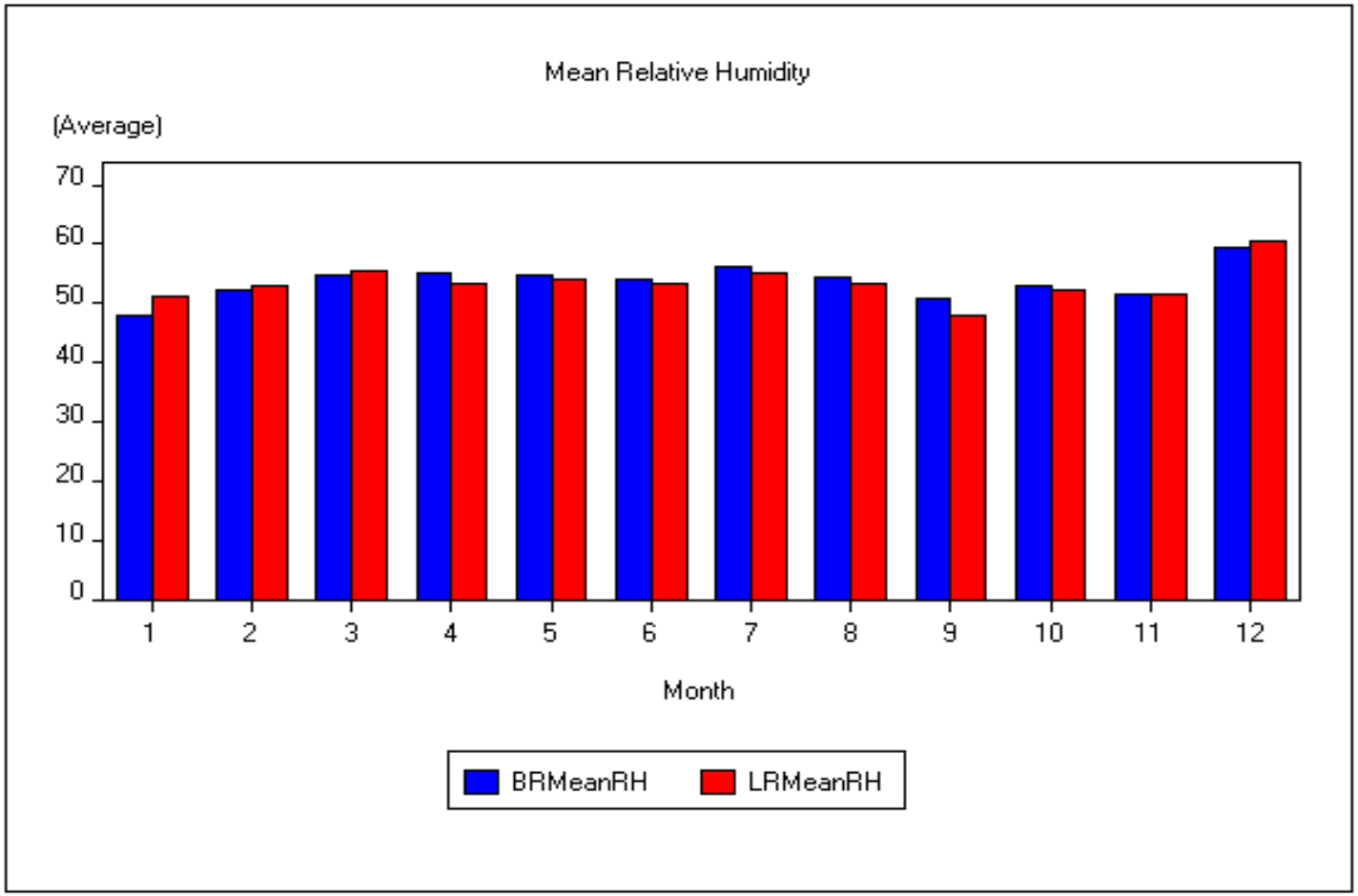
III. Indoor Air Mold / Moisture

III. Measures of Moisture

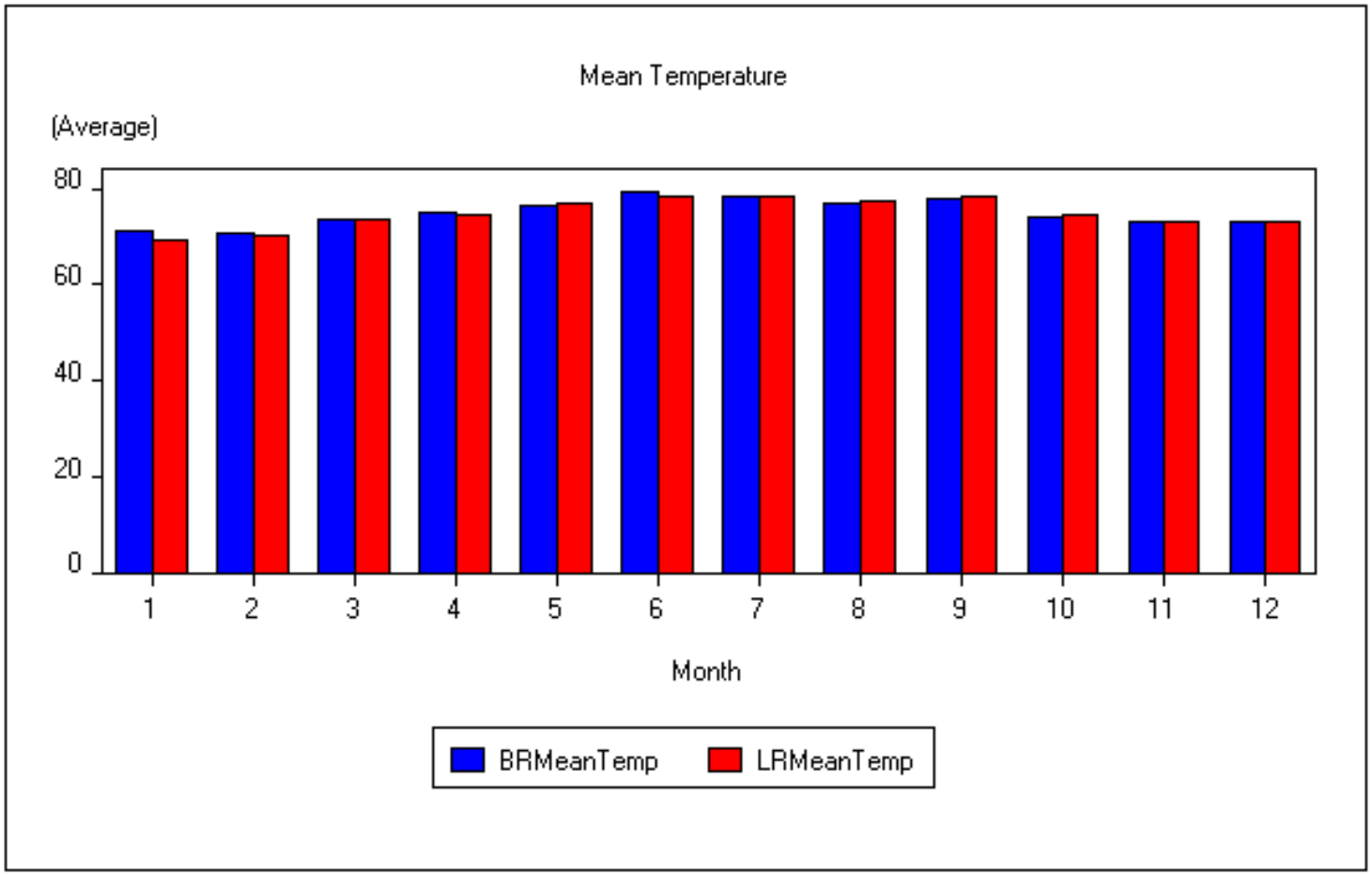
Measure of Moisture	n(%)
Relative Humidity > 50%*	71 (66.9)
Water damage	30 (27.5)
Evidence of Mold/mildew	28 (25.7)
Musty odor	18 (16.5)

*median of 7-day continuous sampling

Indoor Timeline of Relative Humidity



Indoor Timeline of Temperature

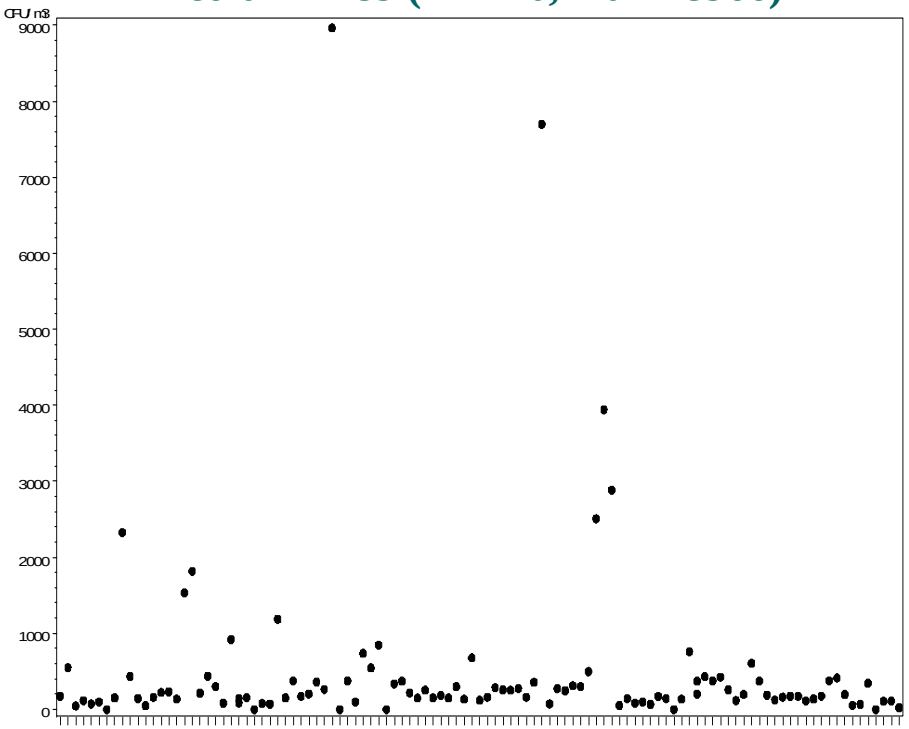


III. Indoor Levels of Air Mold

Total Culturable Air Mold Levels (CFU/m3): Living Room and Bedroom

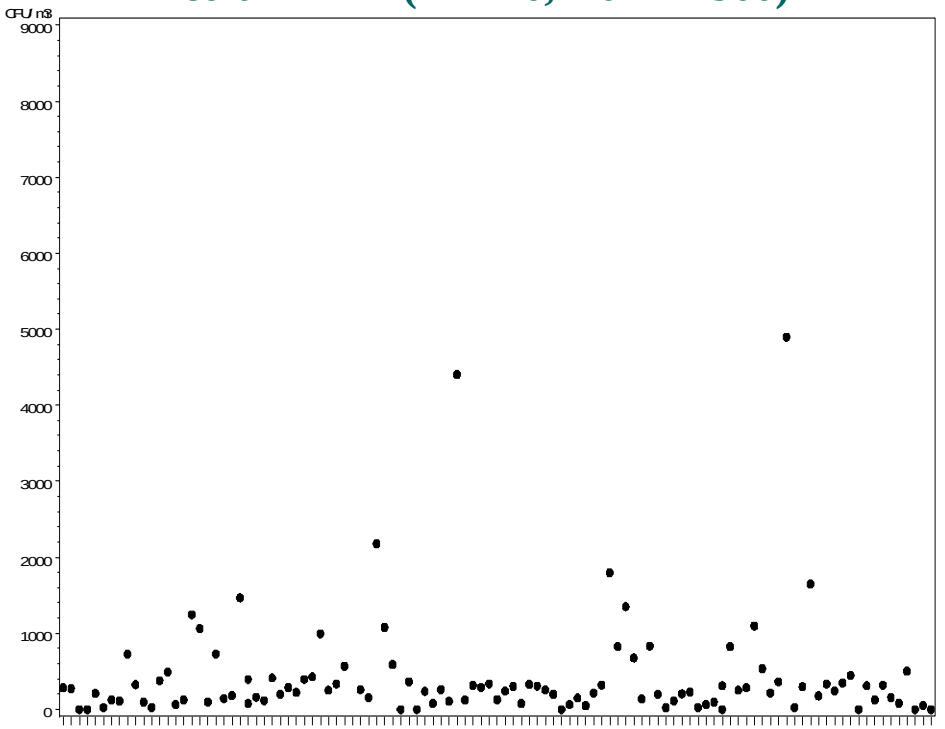
Living Room

Median = 189 (min =0, max =8966)



Bed Room

Median = 247 (min =0, max = 4900)

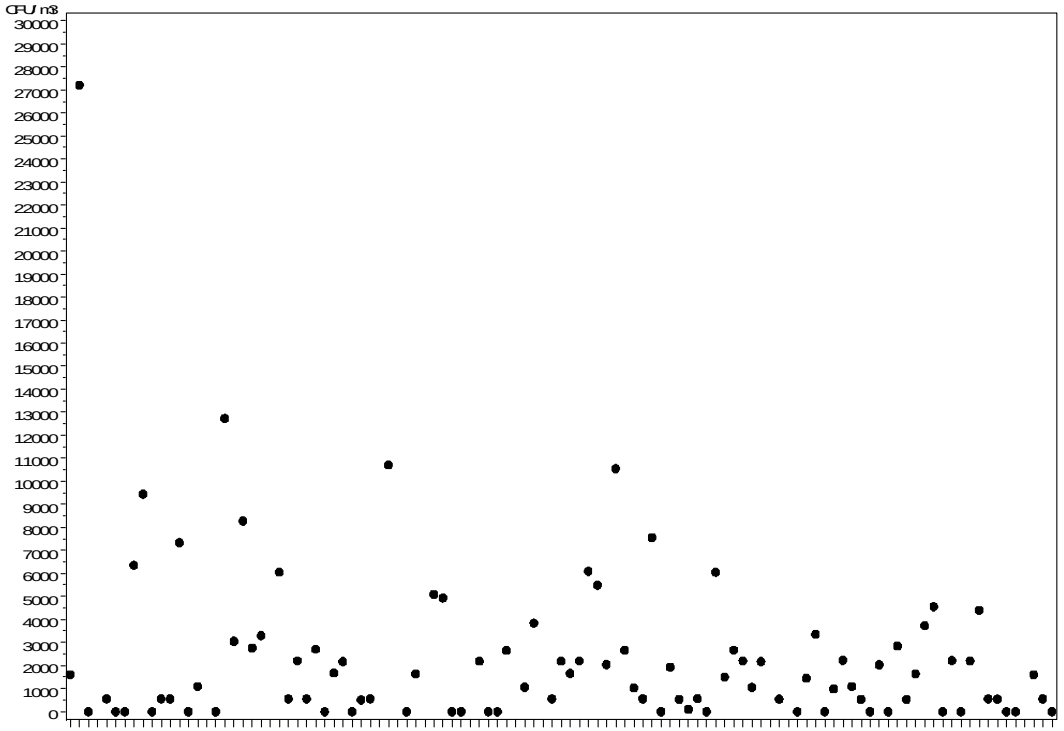


III. Outdoor Levels of Air Mold

Total Culturable Air Mold Levels (CFU/m3): Outdoor Sampling

Outdoor

Median = 1455 (min =0, max =27,218)



26.8% of homes had an I/O Ratio > 1.0 in living room sample

27.8% of homes had an I/O Ratio > 1.0 in living bedroom sample

III. Correlates of Indoor Air Mold level

Are total mold levels higher among those who reported water damage?

Total Mold In the Living room (CFU/m3) for those who had water damage					
N	**Minimum**	**Lower Quartile**	**Median**	**Upper Quartile**	**Maximum**
30	69	150	185.5	413	7700
Total Mold In the Living room (CFU/m3) for those who did not have water damage					
N	**Minimum**	**Lower Quartile**	**Median**	**Upper Quartile**	**Maximum**
79	0	114	189	362	8966

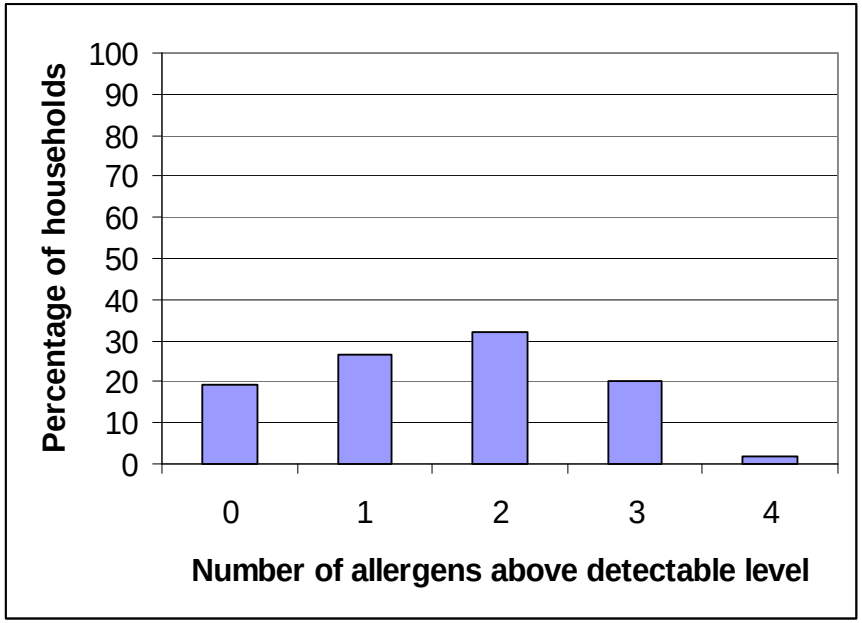
(Wilcoxon Two-Sample Test p = 0.3724)

IV. Dust Allergens

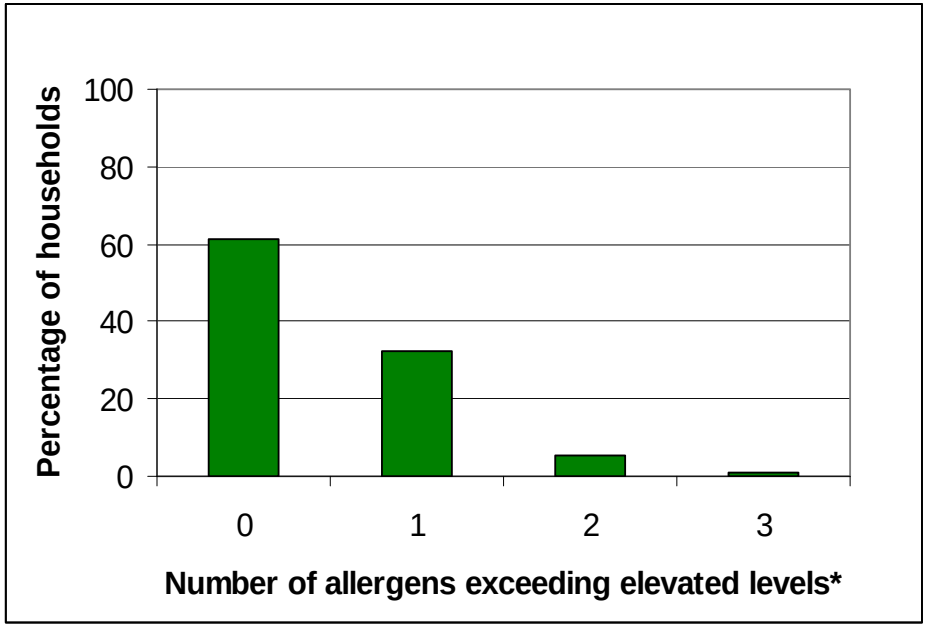
IV. Levels of Indoor Allergens

Allergen Levels	n(%)
Bla g 1 (cockraoch)	
Detectable	20(18.3)
>2 U/g	8(7.3)
>8 U/g	3(2.8)
Either Dust Mite	
Detectable	65(59.6)
>2 ug/g	37(33.9)
>10 ug/g	16(14.7)
Fel d 1 (cat)	
Detectable	57(53.2)
>2 ug/g	24(22.4)
>8 ug/g	13(12.1)
Mus m 1 (mouse)	
Detectable	30(27.5)
>1.6 ug/g	4(3.6)

IV. Overall Burden To Multiple Indoor Allergens



*Includes fel d 1, mus m 1, bla g 1, der p1 or der f 1



*Includes mouse >1.6 ug/g , Bla g 1 >2 U/g, Der p1 or Der f 1 >2 ug/g

IV. Home Renovation Status and Detectable Indoor Allergens*

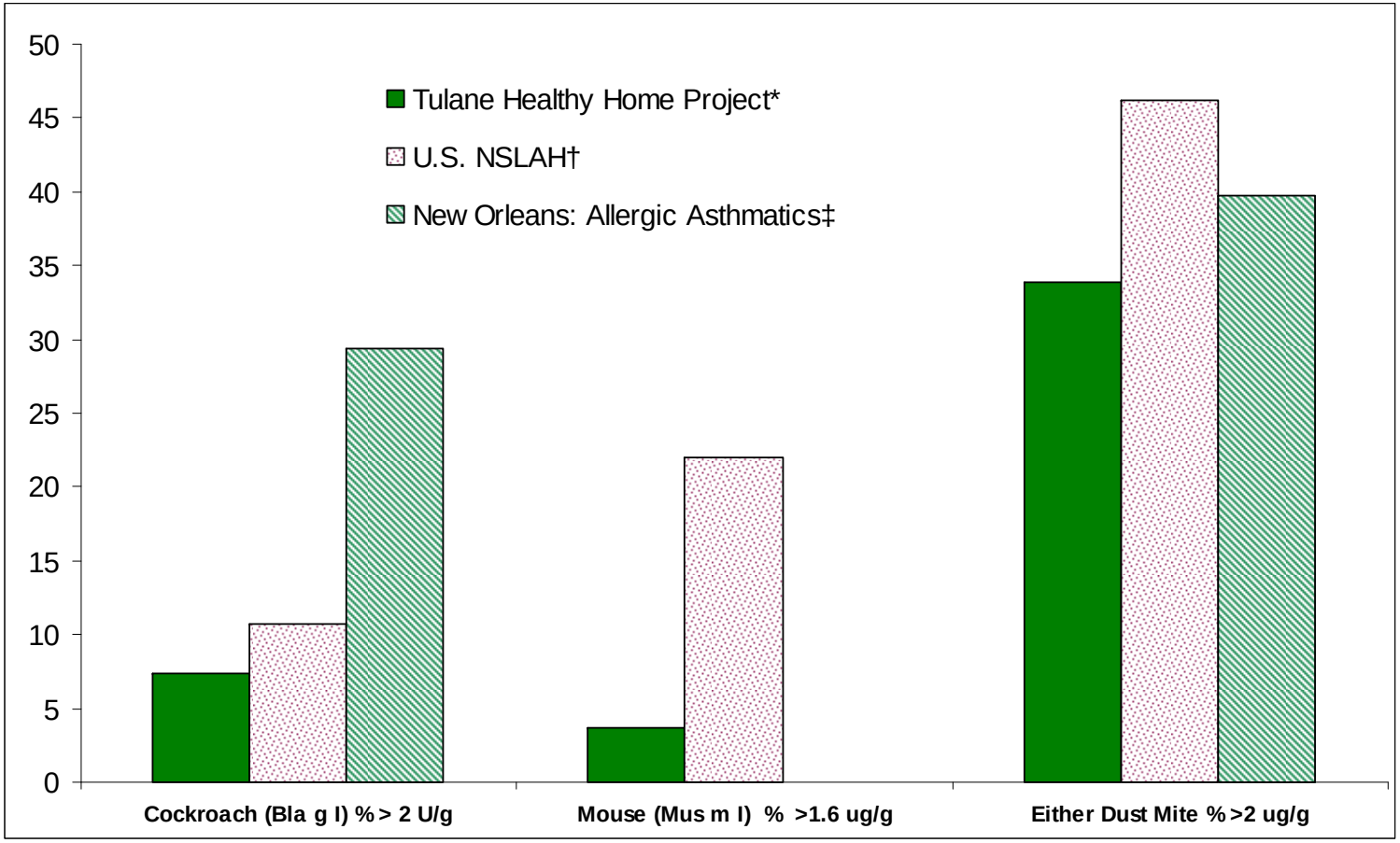
Detectable Levels of Indoor Allergens	No Renovation*	Renovation*	p-value**
Dust Mite (Der p 1 or Der f 1)	25(78.1	38(50.7)	0.009
Mouse (Mus m 1)	11(34.4)	18(24.0)	0.712
Cockroach (Bla g 1)	8(25.0)	12(16.0)	0.274
Cat (Fel d 1)	20(62.5)	36(48.7)	0.19

*Renovation defined as either 1) Renovations/Remodeling are complete, or 2) house is currently under renovation

**P-value for Chi-Square test of association

V. Indoor Dust Allergens

Indoor Dust Allergen: Comparison of New Orleans and National Data



*From LR / BR composite Sample

†Dust mites from master bed, cockroach from LR floor, mouse from kitchen Floor

‡Dust mite from master bed, cockroach from LR floor

Summary

- Lead:
  - Soil lead is a serious problem. 72.4% of pre-1946 houses had elevated levels. The prevalence of elevated soil lead level was found to be independent of income, race, ownership status.
  - Surprising finding given the sample characteristics.

- Dust Allergens:
  - Cockroach: Bla g 1 allergen levels are highly associated with poverty, reinforcing findings from previous studies of asthmatic children.
  - HDM: Driven by features of the home (independent of income). Showed a “cleaning effect” post-Katrina.

- Mold/ Moisture
  - Over half the homes had humidity levels > 50%
  - I/O ratio exceeded 1.0 in a quarter of the homes indicating indoor inhalation is influenced by indoor concentrations.
  - Air mold levels were not associated with water damage or amount of floodwater suggesting mold levels are influenced by features of the home.
- Programs emphasizing healthy home principles are needed in New Orleans to decrease exposure to lead, moisture and cockroach allergen.

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BUILDING A FRAMEWORK FOR HEALTHY HOUSING

Housing Characteristics Associated with Childhood Asthma Triggers: A Pooled Analysis of Nine Studies

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Purpose

- To identify evidence-based elements for inclusion in housing assessment tools for:
  - Assessment of indoor asthma triggers
  - Clinical management of asthmatic children

Problem

- Asthma is serious problem; 8% of the US population diagnosed in their lifetime
- Asthma has been linked to housing conditions, such as:
  - Excessive moisture/mold;
  - Pest allergens;
  - Pesticides
  - Poor indoor air quality (e.g., tobacco smoke)
- Comprehensive housing interventions addressing housing conditions are effective. No evidence-based assessment exists to determine when interventions are needed

Study Design

- NCHH collaborated with the PIs of nine asthma studies to collect and pool their pre-intervention housing assessment data
- NCHH standardized the data and conducted statistical modeling to predict allergen level (high/low)
- Most of the studies collected health data from asthmatic children in the home, but health data were not part of the final analysis

Pooled Studies (1)

Boston Healthy Homes Partnership (Boston Public Health/BMC)	RCT* 91 Homes
Boston Healthy Public Housing Initiative (Boston PHA /BU /Tufts /Harvard)	Intervention* 49 Homes
Cincinnati Asthma Prevention Study (CCHMC)	RCT* 187Homes
Center for Childhood Asthma in the Urban Environment (JHU - Baltimore)	RCT* 89 Homes

Pooled Studies (2)

Urban Mold/Moisture Program Asthma Study (CWR – Cleveland)	RCT* 51 Homes
Urban Mold/Moisture Program Composite Study (CWR – Cleveland)	Observational 50 Homes
Reducing Indoor Allergen Exposures (Columbia – NYC) - IPM	RCT* 29 Homes
Socio-Cultural Influences on Allergic Sensitization (Columbia – NYC)	Birth Cohort 217 Homes
Seattle-King County Healthy Homes II Study	RCT* 187 Homes

Allergen Outcomes

Study	Dust Mite	Cockroach	Mouse	Cat	Dog
BHHP	X	X	X	X	X
BHPHI	X	X	X	X	X
CAPS	X	X		X	X
UMMP	X	X	X		
NY IPM	X	X	X		
NY BC	X	X	X	X	
CAUE	X	X	X	X	X
SHH II	X			X	

Allergen Symptom Thresholds

Dust Mite:	10 µg/g	Der f 1/p 1
Cockroach:	8 U/g	Bla g 1
Mouse:	1.6 µg/g*	Mus m 1
Cat:	8 µg/g	Fel d 1
Dog:	10 µg/g	Can f 1

*No symptom threshold, so sensitization threshold used

Potential Predictors

- Housing Characteristics:
  - Type of building (e.g., single-family)
  - Year built
  - Rental
  - Basement
  - Bedroom floor type (e.g., carpeted)
  - Holes or cracks in walls
- Pets
  - Dog present
  - Cat present

Potential Predictors (2)

- Moisture/Mold - Ventilation
  - Visible mold
  - Mold odor
  - Evidence of water leaks
  - Air conditioner – summer use
  - Dehumidifier - any time
  - Vaporizer - any time
  - Exhaust fan over stove
  - Unvented dryer
  - Type of heating system (e.g., forced air)

Potential Predictors (3)

- Pests
  - Evidence of roaches
  - Roach control used
  - Evidence of rodents
  - Rodent control used
- Other
  - Mattress covers
  - Housekeeping
  - Season sampled

Statistical Process

- Establish a priori list of potential predictors for each allergen
- Using bivariate analysis, identify variables that are predictors of each allergen by study ($p<0.20$)
- Variables that meet $p<0.2$ for at least two studies are eligible for final logistic model. Study site, type of building, and season included in all models
- Using backward elimination, conduct multivariate modeling for each allergen and drop non-significant variables ($p>0.10$)

Dust Mite Results

Predictors of high levels of allergen

- Mold odor OR=2.5
- Absence of basement (single-fam) OR=1.8
- Buildings built before 1951 OR=1.7
- Study site

- 12% of homes > threshold

Cockroach Results

- Predictors of high levels of allergen
  - Visible signs of roaches or use of roach control — OR=6.5
  - Bedrooms with no carpet or less than 50% carpeting — OR=3.9
  - Holes or cracks in walls — OR=2.1
  - Study site — OR=3.2
- 17% of homes > threshold

Mouse Results

- Predictors of high levels of allergen
  - No cats in home OR=5.0
  - Visible signs of rodents or use of rodent control OR=3.6
  - Season sampled
    - Higher in summer/fall than winter/spring
  - Study site
- 26% of homes > threshold

Cat and Dog Results

- Predictors of high levels of cat allergen
  - Cat in home OR=31.2
  - Study site

  14% of homes > threshold
- Predictors of high levels of dog allergen
  - Dog in home OR=98.6

  17% of homes > threshold

Analysis Limitations

- Variables collected using different protocols and metrics
- Pooling of data required collapsing or converting some variable responses
- Data mainly from homes of asthmatic children
- Study site effect necessary but could mask some true associations between a housing condition and allergen levels

Creating Inspection Questions

- Final Objective: Identify key questions for housing assessments
- Limitations:
  - Questions are a subset of a full assessment
  - Unselected questions may still be valid locally
- Factors used to identify questions:
  - Multivariate findings
  - Bivariate findings
  - Sensitivity/specificity of questions
  - Consideration of practical implications

Questions to Identify Cockroach Allergen Hazards

Questions	*Sens.*	*Spec.*	*%ID*
1. Signs of roaches?	80%	60%	45%
2. <50% of bdrm carpeted?	77%	51%	52%
3. Cracks/holes in walls?	72%	55%	51%
4. Evidence of water leaks?	55%	67%	36%
5. Housekeeping < avg?	46%	88%	16%
6. Q. 1 and 5	82%	68%	38%
7. Q. 2 and 4	89%	56%	50%
8. Q. 1, 4 and 5	88%	51%	54%
9. Q. 1, 2 and 5	89%	50%	54%

Questions to Identify Dust Mite Allergen Hazards

Questions	*Sens.*	*Spec.*	*%ID*
1. Home built < 1951?	54%	60%	42%
2. No basement –sing fam?	23%	92%	10%
3. Q.1 and 2	64%	49%	53%

* Mold odor excluded because of inconsistent findings across study sites. Appears valid in high humidity communities like Seattle and Boston.

Questions to Identify Mouse, Cat and Dog Allergen Hazards

Allergen/Questions	*Sens.*	*Spec.*	*%ID*
Mouse			
1. Signs of rodents/use of rodent control?	85%	56%	53%
Cat			
1. Cat present in home?	90%	88%	25%
Dog			
1. Dog present in home?	71%	92%	17%

Use in Clinical Setting

- Questionnaires using these questions may offer benefits but have limitations:
  - Variables used to develop questions generally came from inspections by trained assessors or public records

    Exceptions: Rodent control, presence of cat or dog
  - Variables derived from resident questionnaires were less reliable predictors

Conclusions

- These findings help identify key questions for housing assessments
- Multi-site studies with common protocols and metrics are needed to further advance this research
- There remains a need to establish evidence-based consensus recommendations for housing assessments

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