

Prevalence and Predictors of Residential Health Hazards: A Pilot Study

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*This article reports the results of a pilot study designed to ascertain the prevalence of lead-based paint (LBP), vermin, mold, and safety conditions and hazards and to validate observations and self-reports against environmental sampling data. Data are based on a convenience sample of 70 dwellings in a low-income, urban neighborhood in Brooklyn, New York. The vast majority of residences (96%) contained multiple conditions and/or hazards: LBP hazards (80%), vermin (79%), elevated levels of airborne mold (39%), and safety hazards (100%). Observations and occupant reports were associated with environmental sampling data. In general, the more proximate an observed condition was to an actual hazard, the more likely it was to be associated with environmental sampling results (e.g., peeling LBP was associated with windowsill dust lead levels, and cockroach sightings by tenants were associated with *Blatella germanica* [*Bla g I*] levels). Conversely, the more distal an observed condition was to an actual hazard, the less likely it was to be associated with environmental sampling results (e.g., water damage, alone, was not statistically associated with elevated levels of dust lead, *Bla g I*, or airborne mold). Based on the findings from this pilot study, there is a need for industrial hygienists and others to adopt more comprehensive and integrative approaches to residential hazard assessment and remediation. Further research—using larger, randomly drawn samples, representing a range of housing types and geographical areas—is needed to clarify the relationship between readily observable conditions, occupant reports, and environmental sampling data and to assess the cumulative impact on human health.*

Keywords healthy homes, residential hazards, visual assessment

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Numerous residential hazards have been linked with adverse health outcomes, especially among children. These include: lead-based paint (LBP) hazards with elevated blood lead levels;^(1–3) dampness and fungi;^(4–8) cockroaches,^(9,10) rodents,⁽¹¹⁾ and dust mite allergens with asthma and allergy; and fall, electrical, and fire hazards with injury and death.⁽¹²⁾ Many of these hazards share common underlying causes—most notably, inadequate maintenance, water damage, and chronic moisture. These underlying sources can promote the proliferation of mold, vermin, and peeling paint.⁽¹³⁾ Despite the fact that improperly maintained housing is associated with multiple types of hazards, until recently the vast majority of research, prevention programs, and funding streams have employed a categorical (single issue) approach.⁽¹⁴⁾

Many residential hazards and their health sequelae are disproportionately concentrated in deteriorated, older urban housing stock in low-income neighborhoods.^(15–18) Recently there has been a growing recognition of the need for a more comprehensive and integrative approach to the assessment and remediation of residential environmental hazards, especially in high-risk housing.^(13,19,20) Such an approach makes sense from public health and economic standpoints. It has been suggested that the incremental costs of expanding home environmental assessments (e.g., adding injury to a lead assessment) can be quite modest.⁽²⁰⁾ Additionally, multiple hazards might be more efficiently addressed by correcting a single, shared underlying condition.

Despite the well-established evidence of the link between a number of residential hazards and children's health, many high-risk homes have not been assessed comprehensively⁽²¹⁾ to identify the range of hazards and their associated conditions. Barriers include the fact that traditional assessment sampling methodologies are often cost- and technology-intensive, requiring trained personnel to collect samples and using

sophisticated laboratory methods such as gas chromatography-mass spectrometry (GC-MS) for lead dust loading and enzyme-linked immunosorbent assays (ELISA) for *Blatella germanica* (Bla g 1) allergens. Such approaches may therefore be prohibitive for small, private owners and public housing agencies. Alternatively, there have been some efforts at developing reliable, low-cost approaches to residential hazard assessment. For example, several readily observable housing characteristics such as building age, surface condition, and proximity to traffic, have been found to be predictive of environmental and blood lead levels.^(22–24) Visible mold, dampness, and moisture have been found to predict respiratory symptoms.^(4,6) Housing deterioration is predictive of cockroach allergen levels.⁽¹⁷⁾ Development of accurate, cost-efficient methods of assessing and correcting hazards and their antecedent conditions in high-risk housing is critical to establishing priorities and developing policies to reduce residential hazards and to improving occupant health.

The present study builds on previous research and programs, with a goal toward developing cost-effective, accurate methods for identifying residential environmental hazards in a comprehensive manner. A visual assessment tool for evaluating multiple residential hazards was pilot tested and validated against environmental sampling in a convenience sample of 70 dwellings in a low-income, urban neighborhood in Brooklyn, New York. The study was part of a larger “healthy homes” project designed to test low-cost, low-technology approaches to remediation of residential hazards. The evaluation focused on LBP hazards, vermin, mold levels, and safety conditions and their associated conditions.

In this article, the prevalence of environmental hazards is described; results from the visual assessment are compared with environmental sampling results (where applicable); and the technical and practical implications of the findings for improving low-cost, effective and comprehensive approaches to child health and safety are discussed.

METHODS

Sites and Sample

The target sample consisted of privately owned residences in multiple-dwelling structures (≥ 3 dwellings) in Bedford-Stuyvesant, a low-income, predominately English-speaking, African-American ($>75\%$) community in Brooklyn, New York.⁽²⁵⁾ A dwelling was deemed eligible if (1) both an adult tenant and building owner agreed to participate, (2) a child under 11 years of age resided or spent ≥ 20 hours per week there, (3) it was free of major structural defects, and (4) there was no history of child occupants with lead poisoning.

Potentially eligible dwellings were recruited through contact with building owners at community events, such as block associations and street fairs; referrals from neighborhood housing programs; referrals from participants; and direct, individual contact. An introductory letter and promotional brochure were mailed to each owner, followed by a telephone call. Owners representing 164 potentially eligible buildings were identified

in this manner. To determine whether the dwelling and its occupants met eligibility criteria, owners and adult occupants were interviewed, exterior and interior structures were inspected, and housing violation and blood lead records were obtained from the New York City Departments of Housing Preservation and Development (HPD) and Health and Mental Hygiene (DOHMH), respectively and reviewed.

Of the 164 potentially eligible buildings, 125 were excluded for the following reasons: history of serious, uncorrected building violations ($n = 87$); no children < 11 years of age currently in residence ($n = 13$); located outside the target community ($n = 2$); owner or tenant refused to participate ($n = 13$); owner or tenant responded after all eligible slots had been filled ($n = 10$). In addition, one unit was used to pilot test procedures but was not included in the final sample. The final sample consisted of 38 multiple-dwelling, residential buildings from which 70 dwellings meeting eligibility criteria were enrolled (100% of target). Ninety-nine percent of the participants ($n = 69$) were English-speaking, non-Hispanic African or Caribbean American; one was Spanish-speaking.

Data Collection

Environmental assessments, consisting of visual assessments, interviews and environmental sampling, were conducted in all 70 participating dwellings between August 2001 and May 2002. On completing each environmental assessment, specimens were sent for laboratory analysis and questionnaire data were compiled.

Visual Assessment and Interview

A 1- to 2-hour visual assessment and interview with an adult occupant in each dwelling was conducted. Information was gathered on maintenance history of the building and dwelling; interior and exterior underlying conditions that might contribute to household hazards (e.g., water damage/leaks, nearby construction); conditions directly associated with hazards, including peeling paint, presence of vermin, visible mold; and safety hazards. Items were adapted from several existing instruments.^(26,27) Housing data on the target neighborhood was obtained from the 1980 and 2000 U.S. Census data, as compiled and provided by Infoshare Online.^(28,29)

The visual assessments were conducted by community residents with backgrounds in community organizing and/or housing and who were hired by community-based housing organizations to work on the project. Four staff attended an intensive 2-week training session on residential hazards, health effects, remediation methods, and data collection. Interviews were conducted in the respondents' primary language—69 in English and 1 in Spanish. Results were recorded on a personal digital assistant using Pendragon Forms Software, v. 3.1 (Pendragon Software Corporation, Libertyville, Ill.).

Environmental Sampling

Environmental sampling for deteriorated cockroach allergen, lead dust, and mold was conducted by master's degree students in environmental and occupational health sciences. Students attended an intensive 2-week training session, under

the supervision of a Certified Industrial Hygienist/Certified Safety Professional (CIH/CSP) faculty advisor. In addition, U.S. Environmental Protection Agency (EPA)-certified lead inspectors, primarily from the DOHMH Lead Poisoning Prevention Program, conducted sampling for deteriorated LBP.

Lead-Based Paint Hazards

Significantly deteriorated painted surfaces, as defined by the U.S. Department of Housing and Urban Development (HUD)⁽³⁰⁾ and EPA,⁽³¹⁾ were tested for lead content using either a NITON XL-309 or a RMD LPA-1 X-ray fluorescence (XRF) lead analyzer in accordance with HUD procedures and the applicable Performance Characteristic Sheets.⁽³²⁾ Dust wipe samples were collected from floors and interior window sills in living rooms and bedrooms, following HUD procedures.⁽³²⁾ In all living rooms and bedrooms, a minimum area of 1 square foot from the center of the floor and at least one window sill were sampled. Where possible, hard surfaces (instead of carpeted areas) were sampled. Lead-free ASTM-approved⁽³³⁾ individually packaged wipes were used to collect samples.

Airborne Mold

Viable airborne mold was assessed using the following standardized procedures.^(34,35) Two exterior and two to three interior air samples were collected using an Anderson N6 single-stage impactor (Thermo electron Corporation, Franklin, Mass.) The flow rate was 28.3 L/min with a 1.5 min sampling time, producing a total volume of 42.5 L of air. Exterior air samples were taken at curbside at a height of 5 feet, both before and after the interior assessment (usually within 1 hour of each other). Interior samples were taken 5 feet above the floor in a central location of the living room, child's bedroom, and a second bedroom, when available. Sampling was done under quiescent room conditions. Samples were collected on laboratory prepared malt extract agar petri dishes containing the inhibiting antibiotic chloramphenicol.

Cockroach Allergen

Dust samples were collected from the kitchen, living room, and youngest child's bedroom floor and analyzed for Bla g1 allergen. Samples were collected using an open face 25-mm sampling cassette with a 0.8 micron mixed cellulose ester filter. The cassette was attached to a high-volume pump pulling 28.3 L/min of air. Sampling was conducted until enough dust had accumulated so that the filter on the cassette was obscured. For floors, sampling times varied from 1 to 5 min, with floor areas ranging from 2 to 8 square feet. Immediately following sample collection, the sampling area was measured and recorded. On completion, the sampling cassette was sealed and placed in a zip-lock plastic bag, following previously established methods.^(36–38)

IAQ Measurements

Measurements of temperature, relative humidity, carbon dioxide (CO₂), and carbon monoxide (CO) were obtained from the outside of the building at street level and in every room of the dwelling using a GrayWolf IQ 410, a direct-reading

instrument that uses electrochemical sensors (GrayWolf Sensing Solutions, LLC, Trumbull, Conn.). Criteria for "acceptable" CO₂ levels were based on American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) recommendations that indoor levels be no more than 700 ppm above outside levels.⁽³⁹⁾

Laboratory Analysis and Quality Control Procedures

Dust Lead Loading

Samples were analyzed by an American Industrial Hygiene Association (AIHA)-accredited lead laboratory.⁽⁴⁰⁾ Blanks and spiked samples were submitted at a rate of 10% for quality control purposes. Dust wipes were digested with nitric acid and analyzed using flame-atomic absorption spectrophotometry as per EPA methods 3050B/7420.⁽⁴¹⁾ The analytical detection limit was 5 μ g. Results were reported in μ g of lead and converted to μ g of lead per square foot (μ g/ft²), so as to be comparable with dust lead clearance standards established by EPA.⁽³¹⁾

Airborne Mold

Samples were analyzed by an AIHA-accredited environmental microbiology laboratory.⁽⁴²⁾ Samples were cultured at 25°C for 5 days and enumerated for airborne mold. Results were reported as colony-forming units per cubic meter (CFU/m³) for each mold species. Positive-hole correction was not applied by the laboratory, owing to low airborne densities in our samples.

Cockroach Allergen

Samples were sent to a commercial laboratory and analyzed for Bla-g-1 using ELISA.⁽⁴³⁾ The analytical detection limit was 0.2 units per gram (U/g). Results were reported in allergen units per gram.

Statistical Analysis

Statistical analyses were conducted using the statistical analysis package SAS release 8.2 for Windows.⁽⁴⁴⁾ Descriptive statistics were generated for all relevant variables. Thirty-nine out of 317 dust lead samples (12%), representing 19 dwellings, contained lead levels below the level of detection (5 μ g). A value of one-half the detection limit, or 2.5 μ g, was assigned to these samples and Pb/ft² was calculated, following previously established procedures.^(45,46) Similarly, for cockroach allergen, 118 out of 198 samples (60%), representing 55 dwellings, contained cockroach allergen levels that were below the detectable limit (0.2 U/g). A value of one-half the detection limit, or 0.1 U/g, was assigned to these samples. For cockroach allergen and airborne mold, arithmetic means were calculated for each dwelling. For lead dust, arithmetic means were calculated for each surface type (i.e., floors and windows) across dwellings. Values were then transformed using the natural logarithm because the distributions were found to be highly skewed.

Associations between dwelling characteristics, as determined by observer and occupant ratings and environmental

sampling data, were examined with 2×2 contingency tables. For these analyses, univariate hazard predictors (observer/occupant ratings from the visual assessment tool) and environmental sampling results were treated as categorical variables. Dichotomous categories were created for dust lead on floors and window sills (cut points = $40 \mu\text{g}/\text{ft}^2$ and $250 \mu\text{g}/\text{ft}^2$, respectively, based on dust lead clearance standards established by EPA);⁽³¹⁾ Blood lead (cut point = $2 \text{ U}/\text{g}$, the proposed threshold for allergic sensitization);^(37,47) and total airborne mold concentrations (cut point = $1000 \text{ CFU}/\text{m}^3$, an indication of possible indoor sources of fungi).^(48,49) Odds ratios with 95% confidence intervals were calculated as measures of association; each odds ratio was calculated based on the total number of dwellings with valid data for all relevant variables.

RESULTS

A description of dwellings and buildings in the sample, compared with the target neighborhood, Brooklyn Community District 3, Bedford-Stuyvesant, is provided in Table I. Our sample consisted of a higher proportion of medium-sized dwellings (3–4 rooms), in small multiple dwellings (3–4 dwellings), compared with the housing stock in the target neighborhood. Participating buildings were also somewhat older (99% of sample dwellings were constructed prior to 1940 compared to 75% of dwellings in the community overall) and more likely to be owner-occupied (39% vs. 17%). To some extent, these differences can be explained by recruitment strategies and selection criteria employed. Recruitment was often at neighborhood gatherings where owners of small (and generally older) buildings congregated; the presence of a child under age 11 was required for inclusion in the sample. These factors may have led to an overrepresentation of small, older, owner-occupied and bedroom-containing dwellings.

Dwelling Characteristics

The prevalence of environmental conditions and hazards identified through observation and sampling is found in Table II. Significantly deteriorated paint was observed in 96% of dwellings, cockroaches were reported by tenants in 47% of dwellings, evidence of cockroaches was observed in 57% of dwellings, visible mold was observed in 23% of dwellings, and rodents were reported by 67% of occupants. Safety hazards were observed in 100% of dwellings, the most common of which were the absence of a fire safety plan (76%), no working fire extinguisher (71%), and missing window guards (66%), all of which are mandated in New York City.^(50,51) Notably, recent building leaks were reported in almost half of the dwellings surveyed. One unit had a CO level above 9 ppm, the EPA 8-hour National Ambient Air Quality Standard (NAAQS).⁽⁵²⁾ Over 14% of dwellings had CO₂ levels above the recommended threshold of 1100 ppm. This level of concern was derived from the sum of the mean background CO₂ level of our sample, approximately 400 ppm + 700 ppm.⁽³⁹⁾ All dwellings were “naturally” ventilated.

TABLE I. Sample and Neighborhood Housing Characteristics

Housing Characteristic	Sample		Target Neighborhood	
	Number	Percent	Number	Percent
Total Dwellings	70	100%	57,781	100%
Year Structure Built				
≤ 1939	69	99%	24,759	75%
≥ 1940	1	1%	33,021	25%
Total	70	100%	57,780	100%
# Dwellings in Structure				
< 3	0	0%	13,434	23%
3–4	45	64%	16,488	29%
5–9	6	9%	9878	17%
10–19	7	10%	5121	9%
20+	12	17%	12,792	22%
RV, Boat, Van, etc.	0	0%	67	$< 1\%$
Total	70	100%	57,780	100%
Building Height (# floors) ^A				
(1–3)	16	23%	31,076	57%
(4–6)	54	77%	18,016	33%
(7–12)	0	0%	2523	5%
(13+)	0	0%	3219	6%
Total	70	100%	54,834	100%
Total # of Rooms				
1–2	0	0%	8234	14%
3–4	64	91%	27,781	48%
> 4	6	9%	21,766	38%
Total	70	100%	57,781	100%
# of Bedrooms				
0	2	3%	3786	7%
1	21	30%	14,752	26%
2	41	59%	21,118	37%
≥ 3	6	9%	18,125	31%
Total	70	100%	57,781	100%
Tenure (Occupancy status)				
Owner-occupied	27	39%	9791	17%
Renter-occupied	43	61%	40,615	70%
Vacant	0	0%	7374	13%
Total	70	100%	57,780	100%

Notes: Housing data on the target neighborhood was obtained from the U.S. Census for the year 2000 (unless otherwise indicated) as compiled and provided by Infoshare Online. For certain characteristics, the total numbers of housing dwellings under Target Neighborhood may disagree very slightly due to errors in the algorithms used to combine census tracts into community district areas. Some percentages may not add up to 100% due to rounding.

^ASource: U.S. Census, 1980 data as provided by Infoshare, Online.

Environmental Sampling Results

As shown in the footnotes to Table II, the arithmetic mean (AM), geometric mean (GM) dust lead levels (DLLs) were $39.9 \mu\text{g}/\text{ft}^2$ and 8.4 , respectively, and the geometric standard deviation (GSD) was 5.8 for floors. The AM and GM DLLs were $409.9 \mu\text{g}/\text{ft}^2$ and 126.3 , respectively, and the GSD was

TABLE II. Prevalence of Lead-Based Paint, Mold, Cockroach, and Safety Hazards by Dwelling

Hazard	Hazard Assessment Method		
	Observation n (%)	Environmental Sampling n (%)	Both Observation and Sampling n (%)
Peeling lead-based paint hazard	67 ^A (96)	49 ^B (70)	49 (70)
Dust lead	N/A	28 ^C (40)	N/A
Mold ^D	8 (23)	14 ^E (40)	5 (14)
Cockroach	40 (57)	18 ^F (26)	18 (26)
Safety ^G	70 (100)	N/A	N/A

^A Any observed peeling paint.

^B ≥ 1.0 mg/cm².

^C ≥ 40 μ g/ft² and ≥ 250 μ g/ft² on floors and window sills, respectively. The arithmetic mean (AM) and geometric mean (GM) dust lead levels were 39.9 μ g/ft² and 8.4, respectively, for floors; and 409.9 μ g/ft² and 126.3, respectively, for window sills. The geometric standard deviations (GSDs) were 5.8 and 5.0, for floors and window sills, respectively.

^D Based on 35 dwellings where airborne mold was sampled.

^E Total airborne mold ≥ 1000 CFU/m³. The AM and GM mean airborne mold levels were 959.2 and 566.8 CFU/m³, respectively.

^F Bla g 1 ≥ 2 U/g for the unit mean of the bedroom, living room, and kitchen. The AM and GM Bla g 1 level was 2.9 and 0.6 U/g, respectively.

^G Safety hazards included any of the following: missing smoke detector(s), n = 39 (6%); missing fire safety plan, n = 53 (76%); missing/nonfunctioning fire extinguisher, n = 50 (71%); missing window guard(s), n = 46 (66%); or the presence of an electrical safety hazard (overloaded extensions cords, inappropriately placed wiring, outlets in need of cover plates), n = 18 (26%).

5.0 for window sills. Dust lead levels exceeded current EPA standards for floors and window sills in 19% and 35% of sampled dwellings, respectively. Altogether, 80% (n = 56) of sampled dwellings had significant lead-based paint hazards, in the form of either deteriorated paint or dust lead. The AM and GM Bla g 1 levels were 2.9 and 0.6 U/g, respectively. Mean cockroach allergen levels ≥ 2 U/g were found in 26% (n = 18) of sampled dwellings. Elevated airborne mold concentrations (≥ 1000 CFU/m³) were found in 40% (n = 14) of dwellings sampled. The AM and GM airborne mold levels were 959.2 and 566.8 CFU/m³, respectively.

Associations between dwelling characteristics and measured environmental hazards are presented in Tables II and III. Of the 67 dwellings with significantly deteriorated painted surfaces, 49 (70%) contained lead, as statutorily defined.⁽³⁰⁾ Dust lead levels in the few dwellings containing fully intact surfaces were much lower than in dwellings with deteriorated surfaces (GM: 1.7 vs. 9.1 μ g/ft²). Because $<5\%$ of dwellings had fully intact surfaces, the relationship between damaged LBP (rather than intact paint) and DLL was examined. Damaged LBP and recent building repairs were both significant predictors of hazardous DLLs on window sills [OR = 16.8, (95% CI = 2.1, 135.6); and OR = 2.9, (95% CI = 1.1, 8.3), respectively]. None of the possible predictors of dust lead on

floors reached statistical significance; however, the magnitude of several odds ratios was greater than 2.0 and in the expected direction.

Occupant and observer reports of cockroaches were significant predictors of elevated Bla g 1 levels [OR = 5.9, (95% CI = 1.7, 20.5); OR = 4.7, (95% CI = 1.5, 15.1), respectively]. The odds ratios for visible mold/water damage and cracks, gaps and clutter with elevated Bla g 1 were both greater than 2.0 but did not reach statistical significance. None of the dwellings exhibited moldy odors, and none of the possible predictors of elevated airborne mold levels reached statistical significance, although the ORs for water damage and visible mold were greater than 2.0. In separate analyses (not presented), using lower cutoffs (5 μ g/ft² for dust lead and 0.2 U/g for Bla g 1), several additional dwelling characteristics reached statistical significance, including evidence of water damage, cracks/gaps, and clutter for Bla g 1 and damaged LPB surfaces for dust lead on floors.

The vast majority of residences (96%) contained more than one type of hazard: 22% contained two types of hazards, 54% contained three types of hazards, and 19% contained all four types of hazards. The prevalence of each type of hazard was as follows: 80% of dwellings contained lead-based paint hazards (peeling lead-based paint or elevated levels of lead dust); 79% contained vermin (reports of cockroaches or rodents or hazardous levels of Bla g 1 allergen); 39% of dwellings contained mold (visible mold or elevated levels of mold in air); and in 100% of dwellings, safety hazards (fire, electrical and/or fall hazards) were present.

DISCUSSION

This pilot study contributes to a small but growing body of literature on the efficacy of comprehensive industrial hygiene approaches to residential environments. There is mounting evidence that multiple hazards often coexist (e.g., multiple asthma triggers^(53,54) and peeling LBP hazards).⁽⁵⁵⁾ Global approaches to home remediation (e.g., simultaneously controlling asthma triggers such as dust mites, vermin, mold, and environmental tobacco smoke) have been shown to result in measurable health improvements, for example, reductions in asthma symptoms⁽⁵⁶⁾ and asthma hospitalization.⁽⁵⁷⁾

Among our convenience sample of nondilapidated, older, privately owned, urban dwellings, the vast majority contained multiple problems. Had this study focused on any single condition, the preponderance of risks would have been missed. It is striking that among the conditions assessed, electrical, fire and/or fall hazards predominated. The remedies to these common safety problems are comparatively simple and inexpensive (e.g., installation of smoke detectors, fire extinguishers, fire safety plans, and window guards.) Lead-based paint hazards and vermin were also widespread.

Previously published reports on the prevalence of individual hazards are available with which to compare our findings. The prevalence of LBP hazards found here (80%) may overestimate

TABLE III. Univariate Predictors of Lead, Cockroach Allergen, and Mold Levels

Parameter	Predictor Variable	N	GM	%	OR	95% CI
LBPH				Floor Dust Level ($\geq 40 \mu\text{g}/\text{ft}^2$)		
	Any damaged paint surfaces	Yes 59	9.1	20%	N/A	N/A
		No 3	1.7	0%		
	Any damaged LBP surfaces	Yes 42	13.3	24%	2.8	0.6–14.3
		No 20	3.2	10%		
	Heavy traffic/construction (within 1 block)	Yes 12	2.7	0%	N/A	N/A
		No 50	11.0	24%		
	Bldg. repairs (past 6 mos.)	Yes 24	12.0	25%	2.6	0.6–10.4
		No 35	5.9	11%		
	Water damage in dwelling	Yes 17	14.9	35%	3.3	0.8–12.9
		No 35	8.6	14%		
	Damaged bare floors	Yes 9	24.1	33%	2.4	0.5–11.6
		No 53	7.0	17%		
	Children play on bare soil	Yes 14	7.5	0%	N/A	N/A
		No 47	8.0	23%		
				Windowsill Dust Level ($\geq 250 \mu\text{g}/\text{ft}^2$)		
	Any damaged paint surfaces	Yes 66	134.0	36%	N/A	N/A
		No 3	37.0	0%		
	Any damaged LBP surfaces	Yes 49	210.6	47%	16.8	2.1–135.6
		No 20	36.1	5%		
	Heavy traffic/construction (within 1 block)	Yes 12	103.0	25%	0.6	0.1–2.4
		No 57	131.9	37%		
	Bldg. repairs (past 6 mos.)	Yes 26	223.6	50%	2.9	1.1–8.3
		No 39	80.8	26%		
	Water damage in dwelling	Yes 19	174.1	47%	1.9	0.6–5.7
		No 40	142.1	33%		
Bla g 1				Bla g 1 ≥ 2.0 U/g		
	Cockroaches observed by occupant	Yes 33	1.1	42%	5.9	1.7–20.5
		No 36	0.3	11%		
	Cockroaches observed by HSS	Yes 18	1.7	50%	4.7	1.5–15.1
		No 51	0.4	18%		
	Mold or water damage	Yes 18	1.3	39%	2.3	0.7–7.4
		No 51	0.4	22%		
	Exposed food/crumbs/containers	Yes 40	0.6	25%	0.9	0.3–2.6
		No 29	0.5	28%		
	Cracks, gaps, clutter	Yes 49	0.8	33%	4.4	0.9–21.2
		No 20	0.2	10%		
	Pets in household	Yes 17	0.4	18%	0.5	0.1–2.1
		No 52	0.6	29%		
Airborne mold				Mold ≥ 1000 CFU/m ³		
	Water damage in dwelling	Yes 12	645.5	42%	2.9	0.6–14.0
		No 20	572.5	20%		
	Visible mold	Yes 2	982.4	38%	2.1	0.4–11.4
		No 27	483.0	22%		
	Carpets or rugs	Yes 23	589.9	26%	1.1	0.2–5.3
		No 12	528.5	25%		
	Drapes or curtains	Yes 30	502.7	20%	0.2	0.0–1.2
		No 5	1176.2	60%		
	Pets in household	Yes 6	512.9	17%	0.5	0.1–5.2
		No 29	584.1	28%		

the true extent of the problem. Our findings were much higher than a recent national survey of housing (25%), although they were increasingly comparable for similar subsets of housing, that is, housing occupied by low-income residents (38%), housing in the Northeast (40%), and housing constructed prior to 1940 (68%).⁽¹⁵⁾ An estimated two million dwellings in New York City (63%) are thought to contain LBP.⁽⁵⁸⁾ A possible explanation for the high prevalence reported here is that our convenience sample, as noted earlier, contained a disproportionate number of pre-1940 dwellings, increasing the likelihood that LBP hazards would be present.

The prevalence of elevated levels of indoor airborne mold was also similar to at least one recent national study,⁽⁵⁹⁾ although there are only a limited number of published reports with which to compare these data. The prevalence of elevated cockroach allergens (≥ 2 U/g) in living rooms and bedrooms found in our study (26%) was comparable to at least one major urban study^(16,36) but somewhat lower than what others have found, particularly in kitchens in dilapidated housing.^(17,57) The finding of lower levels in our study may be due both to the exclusion of dilapidated sample from our sample and, to a lesser extent, to the relatively lower flow rate of our sampling pump vs. vacuum methods.^(17,57)

Occupant reports and interviewer observations were fairly reliable in identifying certain environmental hazards, namely, damaged lead-based paint surfaces, recent building repairs, and cockroach sightings. In general, the more proximate the observed or reported condition to an actual hazard, the more likely it was to be associated with environmental sampling results. Deteriorated LBP was associated with window sill DLL, a finding that is consistent with previous studies.^(15,60) Also similar to other investigations,⁽³⁶⁾ cockroach sightings by occupants were associated with cockroach allergen levels.

Conversely, the more nonspecific or distally related the observed or reported condition was to an actual hazard, the less likely it was to be associated with environmental sampling results. For example, water damage, alone, was not statistically associated with elevated levels of dust lead, cockroach allergen, or airborne mold. This finding is not unexpected. Although water damage has been associated with airborne mold in some previous investigations,^(61–63) other investigations have failed to confirm this association.^(61,64,65) These inconsistencies may reflect the fact that airborne mold levels can be associated with a variety of home and environmental characteristics (in addition to water damage) such as moldy odors, ventilation type, season, relative humidity, and pets.^(64–66) These factors have not been assessed uniformly across studies. In our study, small sample size and lack of sample variability limited our ability to assess such potentially relevant factors as seasonality (the majority of measurements were collected in the late spring and fall) and moldy odors (moldy odors were not detected in any of the sample dwellings).

Some additional limitations in our study also deserve mention here. The lack of sampling variability and the failure to assess potentially relevant home characteristics limited our analyses of lead-based paint hazards, mold, and vermin. Specif-

ically, housing age and general housing “condition” have been associated with dust lead levels in investigations by others.^(22–24,60) All but one building in our sample was constructed prior to 1940, all but three dwellings contained some peeling paint, and those with extensive structural damage were excluded. Similarly, the contributions of temperature and relative humidity to mold levels were difficult to assess as only four apartments were assessed during summer, and very few had an elevated temperature ($\geq 80^{\circ}\text{F}$) or relative humidity ($\geq 60\%$).

Also, while certain housing conditions were found to be statistically associated with environmental measurements, several potentially important dwelling, building, community, and occupant level factors were unmeasured in this study: rodent allergen; building structural and systems integrity; within-building variability; and occupant education, income, and behavior (e.g., pesticide use, housekeeping, use of windows, and bathroom and kitchen fans to reduce moisture).

Even where statistically significant associations between observations and environmental sampling results were noted, the degree of association between observer ratings and the relevant environmental sampling results was imperfect (e.g., only 70% of dwellings having peeling paint contained lead; only 51% of dwellings with significantly deteriorated lead based paint had elevated mean levels of dust lead on floors or window sills; 40% with cockroach sightings had elevated allergen levels; and visible mold was not always associated with high airborne concentrations). There are several possible explanations for this. In addition to the unmeasured factors noted above, it is possible that visual observations reflect current conditions, whereas environmental sampling results may reflect longer-term accumulation of dust. Finally, the cutoffs used here were somewhat arbitrary, that is, mold, cockroach allergen, and dust lead are present at lower levels.

Given the widespread yet undocumented nature of many urban residential hazards, there is a need to develop reliable, technologically feasible, and cost-effective assessment methods such as this one. In spite of limitations noted above, this pilot study has several implications for future practice and research.

First, our results show that a visual assessment is reasonably predictive of hazards, particularly lead-based paint hazards, cockroaches, and safety hazards.

Second, visual assessment is technologically and economically feasible, especially compared with environmental sampling. In our study, the costs for laboratory analysis of environmental samples alone amounted to approximately \$250.00 per dwelling. This figure does not include the additional cost of sampling equipment, materials, technician time, sample preparation, and compilation and reporting of results, which, in the private sector, could amount to hundreds of dollars more per dwelling. By contrast, visual assessment costs are relatively modest—primarily developing an assessment tool to record observations and responses and training staff.

Third, local housing and other community organizations can be trained to accurately conduct home assessments. This comprehensive approach could also be extended beyond

homeowners to housing inspectors, building maintenance staff, and others. Such an effort could produce substantial and lasting benefits, strengthening individual, organizational and community capacity to address environmental health issues. Indeed, there is growing recognition that efforts to improve housing (as well as other public health problems) must be aimed at these multiple levels to be more effective.^(14,67) This approach could result in efficiencies for housing and building inspectors by having one individual trained to do integrative, multiple-hazard assessments rather than sending several individual experts to conduct separate assessments for vermin, mold, lead, and safety hazards, as is often the case now.

Finally, increasing community capacity could serve to address the shortage of building and housing inspectors, which many municipalities now face. In conclusion, based on the findings from this pilot study, there is a need for a more comprehensive approach to training, assessment, and remediation of housing conditions on the part of industrial hygienists, building owners, inspectors, assessors, contractors, and maintenance personnel. Further research using larger, randomly drawn samples representing a range of housing types and geographical areas is needed to clarify the relationship between readily observable conditions, occupant reports, and environmental sampling data and to assess the cumulative impact on human health.

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