Prevalence of Lead Hazards and Soil Arsenic in U.S. Housing

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Abstract **The American Healthy Homes Survey, June 2005—March 2006, measured levels of lead and arsenic in homes nationwide. Based on a three-stage cluster sample of 1,131 housing units, key statistically weighted estimates of the prevalence of lead-based paint (LBP) and LBP hazards associated with paint, dust, and soil, and arsenic in dust and soil, were as follows: 37.1 million homes (35%) had some LBP; 23.2 million (22%) had one or more LBP hazards; 93% of the homes with LBP were built before 1978. The highest prevalence of LBP and LBP hazards was in the Northeast and Midwest. Over three million homes with children under six years of age had LBP hazards, including 1.1 million low-income households (<$30,000/yr.). Less than 5% of homes had detectable levels of arsenic in dust (≥5 µg/ft²). Arsenic in soil (for homes with yard soil) averaged 6.6 parts per million (ppm). Many homes had soil arsenic levels of 20 ppm or greater, including 16% of homes with wooden structures in the yard and 8% of homes without such structures.**

Introduction

Childhood lead exposure remains a critical environmental health issue in the U.S. A review by the National Toxicology Program found sufficient evidence for reduced IQ and an increased incidence of behavior problems at blood lead levels (BLLs) below 5 µg/dL (U.S. Department of Health and Human Services [DHHS], 2012). As no safe level of lead exposure for children has been established, the Centers for Disease Control and Prevention (CDC) have adopted a reference value for blood lead in children (currently 5 µg/dL) that is based on the 97.5th percentile of BLLs in U.S. children aged 1–5 years (CDC, 2013). Reducing mean BLLs in children and reducing the number of U.S. homes with lead-based paint (LBP) hazards are national Healthy People 2020 objectives (DHHS, 2015).

Lead in house dust is the strongest predictor of children's BBLs; ingestion by hand-to-mouth activities in young children is the predominant exposure pathway (Dixon et al., 2009; Lanphear et al., 1998; Lanphear & Roghmann, 1997). Lead from deteriorated or disturbed paint contributes significantly to lead in house dust and soil; lead-contaminated soil is also a potential direct exposure source for young children (Gaitens et al., 2009; Lanphear et al., 1996; Mielke & Reagan, 1998).

In 1998–1999, the U.S. Department of Housing and Urban Development (HUD) and the National Institute of Environmental Health Sciences sponsored the National Survey of Lead and Allergens in Housing (NSLAH) (HUD, 2001, 2002). NSLAH included the assessment of homes for the presence of LBP and LBP hazards and the concentrations of common allergens in house dust (Jacobs et al., 2002, Salo et al., 2008). The American Healthy Homes Survey (AHHS) was conducted June 2005 through March 2006 to update the NSLAH and study additional environmental analytes of interest.

AHHS measured levels of lead, LBP hazards, allergens, and endotoxin in homes nationwide, as did NSLAH. AHHS also included analysis for additional environmental contaminants, including arsenic, pesticide residues, and mold (Stout et al., 2009; Vesper et al., 2007). This article includes estimates of the prevalence of LBP and significant lead hazards in paint, dust, and soil, for all housing and for important subpopulations of housing defined by region, age, presence of children under age six, income, housing type, race, housing tenure, government support, and ethnicity. Estimates of arsenic levels in soil are also provided. Because AHHS was designed to ensure a high degree of comparability to NSLAH for lead, differences between AHHS and NSLAH lead estimates are presented.

TABLE **1**

Prevalence of LBP[a] in the American Healthy Homes Survey by Housing Characteristic

Housing Unit (HU) Characteristic	All HUs[b,c,d]	# HUs With LBP[c]			% HUs With LBP			HUs in Sample
		Estimate	Lower 95% *CI*[e]	Upper 95% *CI*	Estimate	Lower 95% *CI*	Upper 95% *CI*	
Total HUs[c]	106,033	37,058	34,047	40,068	34.90	32.10	37.80	1,131
Region								
Northeast	20,190	10,121	8,722	11,519	50.10	43.30	57.00	196
Midwest	23,994	9,358	7,924	10,791	39.00	33.40	44.60	245
South	38,996	11,003	9,114	12,892	28.20	23.20	33.30	440
West	22,853	6,576	5,345	7,808	28.80	23.80	33.80	250
Construction year								
1978–2005	40,458	2,675	1,458	3,893	6.60	3.60	9.60	476
1960–1977	29,956	7,376	5,761	8,991	24.60	19.50	29.80	306
1940–1959	18,117	11,921	10,645	13,197	65.80	58.60	73.00	187
Before 1940	17,502	15,085	13,932	16,239	86.20	79.70	92.70	162
One or more children under age 6								
All income categories	16,833	5,742	4,237	7,247	34.10	25.20	43.10	207
<$30,000/yr.	5,781	1,978	1,063	2,895	34.20	19.60	48.90	74
≥$30,000/yr.	11,052	3,764	2,491	5,036	34.10	23.40	44.70	133
Household income								
<$30,000/yr.	37,059	14,808	12,632	16,984	40.00	34.20	45.70	401
≥$30,000/yr.	68,975	22,249	19,461	25,038	32.30	28.70	35.80	730
Housing unit type								
Single family	89,156	33,354	30,699	36,010	37.40	34.40	40.40	950
Multifamily	16,877	3,703	2,104	5,303	21.90	13.50	30.40	181
Race								
White	82,739	26,105	23,449	28,760	31.60	28.50	34.60	868
African-American	13,161	5,957	4,292	7,622	45.30	35.10	55.60	151
Other	10,134	4,996	3,467	6,525	49.30	41.70	56.90	112
Tenure								
Owner occupied	73,627	24,513	21,644	27,381	33.30	29.80	36.80	772
Renter occupied	32,407	12,545	10,466	14,624	38.70	32.80	44.60	359
Government support								
Yes	5,870	1,528	724	2,332	26.00	14.60	37.40	65
No	99,522	35,237	32,276	38,199	35.40	32.60	38.20	1,059
Ethnicity								
Hispanic/Latino	13,175	4,860	3,430	6,290	36.90	28.70	45.10	158
Not Hispanic/Latino	92,858	32,198	28,989	35,406	34.70	31.50	37.80	973

[a]Lead-based paint (LBP) defined as paint or other surface coating containing lead at or above 1.0 mg/cm².
[b]HUs include permanently occupied, noninstitutional housing units in which children are permitted to live.
[c]In millions.
[d]All percentages are calculated with "all HUs" in the left-most column of each row as the denominator.
[e]*CI* = confidence interval for the estimated number or percent.

Methods

AHHS was conducted in a nationally representative sample of permanently occupied, noninstitutional housing in which children may live. Vacant housing, seasonal housing, group and senior housing, hotels/motels, and military housing were ineligible for AHHS. Of the estimated 124.4 million U.S. housing units (HUD & U.S. Department of Commerce [U.S. DOC], 2006), the sample frame was the 106 million in which children could live.

Survey Design

The survey design was a three-stage cluster sample of the target population. The first stage consisted of 100 primary sampling units (PSUs—metropolitan statistical areas, single counties, or groups of counties), randomly selected with probability proportional to population according to the 2000 census. The second stage of sampling was to select segments from each PSU with probability proportional to the number of housing units. A segment typically consisted of several city blocks, although it could be much larger in rural areas. The third and final stage of sampling was to select housing units in each segment at random. Ultimately, a sample of 2,224 housing units was drawn, from which 1,131 eligible homes (51%) were recruited and completed the survey. The principal reasons that 49% of sampled homes did not complete the survey were ineligibility (10%), inability to contact a resident (10%), and refusal (23%). Documentation on the details of the design is available (HUD, 2004, 2007).

Field and Laboratory Work

Field operations began in late June 2005 and were completed in March 2006. A two-person team consisted of a trained interviewer and a state-certified LBP inspector/risk assessor. The risk assessor arrived in the PSU five days after the interviewer and began data collection in units already recruited. In each home, the interviewer obtained a signed informed-consent form and then selected four rooms in which sampling was to be conducted: kitchens, common living areas, bedrooms (children's only if present), and all other rooms. If the home had a habitable basement, the largest room in it was also selected. The interviewer administered a questionnaire to a household representative and collected vacuum dust samples for allergen and mold analysis from the floor of the home, and obtained the entire bag from the resident's vacuum cleaner, if possible. Concurrently, the risk assessor conducted portable X-ray fluorescence (XRF) lead testing in paint and other surface coatings, collected dust wipes for lead and arsenic, soil samples in the yard for lead and arsenic, and floor wipe samples for pesticides in a randomly selected subset of 501 homes (Stout et al., 2009). The soil samples were taken in the main entry, on the foundation/dripline, in the middle of the yard, and in play areas.

Sampling and analysis methods, quality control/quality assurance protocols, and an expanded discussion of the data collected are in HUD (2007, 2011).

Data Analysis

Weighted statistical analysis for AHHS was conducted using WESVAR version 4.2. Survey weights were adjusted for nonresponse and poststratified to match the 2005 American Housing Survey (HUD & U.S. DOC, 2006). The JK(n) version of the Jacknife method was used within WESVAR for variance estimation (Wolter, 2003).

Results

LBP in Housing

An estimated 37.1 million homes (35%) had LBP somewhere in the building, down slightly from the NSLAH estimate of 37.9 million (40%) (Table 1). The significant drop in *percentage* of homes with LBP was due to the large number of lead-free homes built since 1978, when residential LBP use was banned. Of homes built before 1978, 34.4 million (52%) had LBP compared to 35.9 million (54%) in NSLAH, a decrease of 1.5 million in seven years.

The prevalence of LBP increased with the age of the housing, reaching 86% for homes built before 1940. A higher percentage of the housing stock in the Northeast and Midwest had LBP compared to the south and west. Of 16.8 million homes with children under six, 5.7 million (34%) had LBP, about the same incidence of LBP as in all homes. Poorer households had significantly more LBP (40%) than more affluent households (32%), as did single-family homes (37%) compared to multifamily homes (22%), and African-American (45.3%) and other race (49%) households compared to white households (32%). No significant differences in LBP prevalence were found by housing tenure, ethnicity, or government support of housing.

Significant LBP Hazards in Housing

A home had a *significant LBP hazard* if it contained deteriorated LBP in greater than *de minimis* amounts (Lead Safe Work Practices, 2004), *or* had dust lead levels above federal thresholds—40 µg/ft^2 for floors, 250 µg/ft^2 for windowsills, *or* had bare soil lead levels above federal thresholds (9 ft^2 of bare soil with a lead concentration of 1,200 parts per million [ppm] or greater, or 400 ppm for bare soil in an area frequented by a child under six).

An estimated 23.2 million homes (22%) had LBP hazards, also down slightly from the NSLAH estimate of 24.0 million (25%) (Table 2). Older homes had more LBP hazards (67% of homes built before 1940), as did homes in the Northeast and Midwest compared to the south and west. Of the estimated 16.8 million homes with children under the age of six, an estimated 3.6 million (21%) had LBP hazards; of 5.8 million households earning less than $30,000 per year with children under six, 1.1 million (20%) had LBP hazards. Homes with children did not differ from all homes in their likelihood of having LBP hazards, even when income was taken into account. Few homes had soil lead hazards (an estimated 3.6%) and even fewer in play areas frequented by children under six—only an estimated 0.5%. Poorer households were significantly more likely to have LBP hazards (29%) than more affluent households (18%), as were single-family homes (25%) compared to multifamily homes (7%), and homes not receiving government support of rental payments (22%) compared to those receiving government support (12%). African-American households were more likely (28%) to have LBP hazards than white households (20%). No significant difference in incidence of LBP hazards was found by tenure or ethnicity.

Significant Differences Between AHHS and NSLAH Lead Estimates

The drop in the percentage of homes with LBP from 40% in NSLAH to 34.9% in AHHS (Table 3) was statistically significant, but only because of the large increase in post-1977 homes in AHHS. At the regional level, in the Midwest, both the number and percentage of homes with LBP decreased significantly from NSLAH to AHHS, as did the percentage with signifi-

TABLE **2**

Prevalence of Significant LBP Hazards[a] in American Healthy Homes Survey by Housing Characteristic

Housing Unit (HU) Characteristic	All HUs[b,c,d]	# HUs With Significant LBP Hazards[c]			% HUs With Significant LBP Hazards			HUs in Sample
		Estimate	Lower 95% *CI*[e]	Upper 95% *CI*	Estimate	Lower 95% *CI*	Upper 95% *CI*	
Total HUs	106,033	23,186	20,532	25,840	21.90	19.40	24.30	1,131
Region								
Northeast	20,190	7,507	6,014	9,001	37.20	29.70	44.70	196
Midwest	23,994	6,398	5,257	7,539	26.70	22.30	31.00	245
South	38,996	6,067	4,454	7,680	15.60	11.50	19.60	440
West	22,853	3,214	2,202	4,225	14.10	9.70	18.40	250
Construction year								
1978–2005	40,458	1,083	453	1,713	2.70	1.10	4.30	476
1960–1977	29,956	3,415	1,899	4,930	11.40	6.50	16.30	306
1940–1959	18,117	6,999	5,391	8,607	38.60	29.70	47.60	187
Before 1940	17,503	11,689	10,425	12,954	66.80	59.60	74.00	162
One or more children under age 6								
All income categories	16,833	3,585	2,205	4,966	21.30	13.10	29.50	207
<$30,000/yr.	5,781	1,138	510	1,765	19.70	8.80	30.60	74
≥$30,000/yr.	11,052	2,447	1,330	3,564	22.10	12.60	31.70	133
Household income								
<$30,000/yr.	37,059	10,635	8,827	12,443	28.70	24.20	33.20	401
≥$30,000/yr.	68,975	12,551	10,027	15,075	18.20	14.70	21.70	730
Housing unit type								
Single family	89,156	21,942	19,478	24,406	24.60	21.90	27.30	950
Multifamily	16,877	1,244	426	2,062	7.40	2.60	12.10	181
Race								
White	82,739	16,778	14,533	19,022	20.30	17.70	22.80	868
African-American	13,161	3,727	2,455	5,000	28.30	20.60	36.10	151
Other	10,134	2,681	1,863	3,499	26.50	19.80	33.10	112
Tenure								
Owner occupied	73,627	15,036	12,167	17,905	20.40	16.70	24.20	772
Renter occupied	32,407	8,150	6,383	9,916	25.20	19.70	30.60	359
Government support								
Yes	5,870	721	205	1,238	12.30	3.00	21.60	65
No	99,522	22,320	19,590	25,050	22.40	19.80	25.10	1,059
Ethnicity								
Hispanic/Latino	13,175	2,400	1,607	3,194	18.20	12.70	23.70	158
Not Hispanic/Latino	95,858	20,786	18,082	23,490	22.40	19.80	25.00	973

[a]Significant lead-based paint (LBP) hazards defined as deteriorated LBP >20 ft^2 exterior or 2 ft^2 interior LBP for large surface area components, or >10 ft^2 of the total surface area on small interior components; OR dust-lead levels >40 µg/ft^2 on floors or 250 µg/ft^2 on windowsills; OR >9 ft^2 of bare soil with a lead concentration >1,200 parts per million (ppm), or 400 ppm in an area frequented by a child under the age of six years.

[b]HUs include permanently occupied, noninstitutional housing units in which children are permitted to live.

[c]In millions.

[d]All percentages are calculated with "all HUs" in the left-most column of each row as the denominator.

[e]*CI* = confidence interval for the estimated number or percent.

cant LBP hazards. The number and percentage of white-owned homes and homes owned by other races (not white or African-American) with LBP also decreased significantly, as did the percentage of white-owned homes with significant LBP hazards. The percentage of multifamily units with significant LBP hazards decreased sharply, from 19% to 7.4%.

AHHS found an estimated 15.3 million homes (14%) with significantly deteriorated LBP, 13.7 million with dust lead hazards (13%), and 3.8 million with soil lead hazards (4%) (Table 4). The comparable numbers from NSLAH were 13.6 million (14%), 15.5 million (16%), and 6.5 million (7%), respectively. The number and percentage of units with soil lead hazards in AHHS and NSLAH are not directly comparable because AHHS collected soil samples only for units where residents had use of an outside area with soil. Even when the number and percentage of units with soil lead hazards in AHHS were adjusted to compare with NSLAH, however, a substantial decrease still occurred in the incidence of soil lead hazards in AHHS (HUD, 2011).

A significant decrease occurred in the number and percentage of homes with both interior and exterior LBP, and in the percentage of homes with very high levels of LBP (≥10 mg/cm^2) (Table 3). The number and percentage of homes built between 1960 and 1977 with significantly deteriorated LBP, however, showed a significant increase.

TABLE **3**

Statistically Significant Differences (p = .05) Between AHHS[a] and NSLAH[a]

Estimate	AHHS	NSLAH
Percentage of HUs[a] with LBP[b]	34.90%	40%
Number of HUs in the Midwest with LBP	9,358,000	11,748,000
Percentage of HUs in the Midwest with LBP	39.00%	53%
Number of white households with LBP	26,105,000	30,945,000
Percentage of white households with LBP	31.60%	40%
Number of other[c] race households with LBP	4,996,000	1,913,000
Percentage of other race households with LBP	49.30%	29%
Percentage of HUs in the Midwest with significant LBP hazards	26.70%	33%
Percentage of multifamily HUs with significant LBP hazards	7.40%	19%
Percentage of white households with significant LBP hazards	20.30%	25%
Percentage of HUs with interior lead dust hazards	13.00%	16%
Number of HUs with both interior and exterior LBP	16,203,000	20,260,000
Percentage of HUs with both interior and exterior LBP	15.30%	21%
Percentage of HUs with LBP ≥10 mg/cm^2	6.00%	14%
Percentage of HUs built 1960–1977—significantly deteriorated LBP	6.10%	2%
Number of HUs built 1960–1977—significantly deteriorated LBP	1,822,000	610,000

[a]AHHS = American Healthy Homes Survey; NSLAH = National Survey of Lead and Allergens in Housing; HUs = housing units; HUs include permanently occupied, noninstitutional housing units in which children are permitted to live.
[b]Lead-based paint (LBP) defined as paint or other surface coating containing lead at or above 1.0 mg/cm^2.
[c]Not white or African-American.

Arsenic Findings

AHHS provides the first statistically valid national estimates of the prevalence of arsenic in household dust and soil. Less than 5% of homes had detectable levels of arsenic in dust (detection limit 5 µg/ft^2), but 3,254 of 3,785 soil samples (86%) had detectable levels (detection limit 1 ppm). Table 5 shows estimates of the national mean level as well as differences by region, housing age, and income. For samples below the detection limit, arsenic levels were calculated from raw analytical files provided by the laboratory. The mean level of arsenic in soil, for homes with soil in the yard, was 6.6 ppm. Arsenic levels increased with the age of the housing and were higher in the Northeast and Midwest than in the south and west. In terms of mean levels and regional variation, the arsenic data appear to be broadly consistent with surface soil levels reported by the U.S. Geological Survey (USGS, 2013).

Regional and age differences were much less pronounced for arsenic than for lead. Demographic and socioeconomic variables that were correlated with the incidence of LBP and LBP hazards were generally not important for arsenic, with the exception of household income. Unlike lead, however, high-income households had higher soil arsenic levels than low-income households.

Homes with wooden structures in the yard had significantly higher levels of arsenic in soil (Table 6), even though soil samples for arsenic were not generally taken adjacent to wooden structures (if any)—70% of homes with wooden structures had soil arsenic levels ≥5 ppm, while only 49% of homes without wooden structures had such levels; 16% of homes with wooden structures had soil arsenic at 20 ppm or greater, a cleanup level used by several states and by the U.S. Environmental Protection Agency (U.S. EPA) in some Superfund cleanup plans, compared to 8% of homes without wooden structures. Wooden structures were not tested.

Discussion

Lead

Some of the significant differences in LBP prevalence (Table 3) reflect incremental progress in reducing LBP over the seven years between NSLAH and AHHS. Fewer housing units had *both* interior and exterior LBP, perhaps due to common lead hazard control actions such as replacing windows that remove some but not all of the LBP in a home. Fewer units had very high levels of lead in paint (i.e., 10 mg/cm^2 or greater), perhaps reflecting hazard control actions directed to eliminating exterior LBP, which tends to have the highest levels of lead, as well as demolition of older housing stock. Because of the strong positive association between paint-lead levels and dust-lead levels, this reduction is also expected to be reflected in reductions in dust-lead levels. The significant nationwide drop in the percentage of housing units with LBP is due mainly to the approximately 10 million lead-free homes built between 1998 and 2005. The 1.5 million reduction in the number of pre-1978 homes with LBP (not statistically significant) equates

TABLE **4**

Prevalence of Significant LBP Hazards[a] in AHHS[b] by Type of Hazard With Comparisons to NSLAH[b]

Type of Hazard	# HUs[c,d]			% HUs		
	Estimate	Lower 95% *CI*[e]	Upper 95% *CI*	Estimate	Lower 95% *CI*	Upper 95% *CI*
Significantly deteriorated LBP	15,331	12,784	17,879	14.50	12.10	16.80
	13,634	*10,928*	*16,341*	*14*	*11*	*17*
Interior lead dust	13,740	11,776	15,704	**[13.0]***	11.20	14.80
	15,468	*12,982*	*17,954*	*16*	*14*	*19*
Soil lead hazard	3,848	2,235	5,461	3.60	2.10	5.20
	6,460	*3,122*	*9,799*	*7*	*3*	*10*
Any LBP hazard	23,186	20,532	25,840	21.90	19.40	24.30
	24,026	*21,306*	*26,746*	*25*	*22*	*28*

[a]Significant lead-based paint (LBP) hazards defined as deteriorated LBP in greater than *de minimis* amounts (deterioration >20 ft² of exterior LBP or 2 ft² of interior LBP for large surface area components, or damage >10 ft² of the total surface area of LBP on small interior components); OR has dust-lead levels above the federal threshold for floors or windowsills (40 µg/ft² for floors or 250 µg/ft² for windowsills); OR has bare-soil lead levels above federal thresholds (more than 9 ft² of bare soil with a lead concentration of 1,200 parts per million [ppm] or greater, or 400 ppm for bare soil in an area frequented by a child under the age of 6 years).

[b]National Survey of Lead and Allergens in Housing (NSLAH) values are in italics below the American Healthy Homes Survey (AHHS) values.

[c]HUs = housing units; HUs include permanently occupied, noninstitutional housing units in which children are permitted to live.

[d]In millions.

[e]*CI* = confidence interval for the estimated number or percent.

*Statistically significant differences from NSLAH (at the 5 level; $p = .05$) shown bolded in square brackets.

to an annual rate of decrease of 0.6% over the seven years between NSLAH and AHHS, consistent with previous estimates of the annual rate of demolition in housing ranging from 0.6% to 0.96% (Jacobs & Nevin, 2006).

The prevalence of LBP in homes built in 1978 through 2005 after the use of LBP in homes was banned was 6.6%, similar to the 7.0% reported for 1978–1998 in NSLAH. In AHHS, 74% of the XRF readings that were positive for LBP in these units were on ceramic surfaces (1.7% of 1978–2005 homes had XRF readings positive for LBP on nonceramic surfaces; some of these positive readings may reflect measurement error). Floor dust-wipe samples were collected on 42 of the ceramic surfaces with positive readings; 39 were below the detection limit (5 µg/ft²), with the highest lead level being 13.1 µg/ft². This suggests that lead in ceramic tile is encapsulated and does not create elevated levels of lead in dust.

The modest drop in the total number of homes with LBP hazards (0.8 million) reflects larger drops in homes with lead dust hazards (1.7 million) and soil lead hazards (2.6 million), offset by an increase in homes with significantly deteriorated LBP (1.7 million). Interestingly, 1.2 million of this last increase was in homes built between 1960 and 1977, perhaps reflecting the aging of this housing stock. These figures suggest that, while the overall number of homes with LBP hazards decreased only modestly in seven years, greater progress occurred in reducing the number of homes with lead hazards in dust and soil. This means reduced overall exposure, dust and soil being the most significant exposure pathways for lead exposure in children, consistent with BLL data showing that children's BLLs declined from 1999 to 2006. Analysis of data from the National Health and Nutrition Examination Survey indicated statistically significant reductions in both the mean BLL of children aged 1–5 and the percentage of children with BLLs ≥5 µg/dL between 1999–2002 and 2007–2010 (CDC, 2013).

The large decrease in the percentage of multifamily units with LBP hazards is noteworthy and likely reflects the influence of HUD's regulations requiring lead hazard control activities in federally subsidized multifamily housing and enforcement of the Lead Disclosure Rule (24 CFR Part 35, Subpart A) by HUD and U.S. EPA. Through 2013, settlements with large multifamily and other landlords found to have violated the disclosure rule required inspections or lead-hazard control work to be conducted in over 180,000 units.

Dust lead hazards were significantly reduced nationwide, perhaps because of the emphasis of most guidance and regulation related to lead hazard control, which is to conduct interim lead hazard controls to manage LBP and lead-contaminated soil in place, without removing all LBP and contaminated soil. The National Evaluation of HUD's Lead Hazard Control Grant Program showed that interim controls yield substantial reductions in residential dust-lead levels and children's BLLs, lasting for several years (Clark et al., 2011, Wilson et al., 2006). The increase in significantly deteriorated LBP in housing built between 1960 and 1977 could be due to greater relative aging in this group and illustrates the importance of maintaining paint condition.

HUD plans to conduct another national survey this decade to track changes in the prevalence and distribution of LBP hazards and possibly other exposures of concern (e.g., allergens, mold) in U.S. housing. As in the previous surveys, the department will look for opportunities to work with its federal partners to maximize the value of the survey as a targeted national surveillance tool.

Arsenic

Higher levels of soil arsenic found for higher-income households are likely due to more wooden structures such as decks and fences in more expensive homes. Although a definitive determination cannot be made based on the soil sampling protocol used in AHHS, this pattern is likely due to the leaching of inorganic arsenic from wood that was treated with chromated copper arsenate (CCA) or to sawdust left in the soil after construction of wooden structures. CCA was used to treat wood used in outdoor residential settings starting in the 1970s, with its use for this purpose discontinued in 2004 as the result of a voluntary agreement between commercial users and U.S. EPA (US. EPA, 2011).

AHHS results have potentially important implications for regulation of arsenic in states. While no federal regulatory lim-

its exist for arsenic in soil, many states have established limits. Of 19 states reporting residential action levels for soil in a 1998 survey (City of Amherst, 1998), 12 were below the AHHS national mean level of 6.60 ppm arsenic in soil. Only two had an action level > 20 ppm. Of 17 reporting cleanup levels, only one exceeded 20 ppm. AHHS estimated that 16% of homes with wood structures in the yard and 8% of homes without such structures (Table 6) had soil arsenic levels of 20 ppm or greater. Thus, the typical levels of arsenic actually found in soil across the U.S. were higher than many state regulatory limits. The health implications for this are unclear. Arsenic is a known human carcinogen, and risk increases with the extent of exposure. Of greatest concern would be the incidental ingestion of arsenic-contaminated soil and dust by young children (Agency for Toxic Substances and Disease Registry, 2007).

TABLE **5**

American Healthy Housing Survey Mean Soil Arsenic Levels by Housing Characteristic

Characteristic	Soil Arsenic (parts per million)		
	Mean	Lower 95% *CI*[a]	Upper 95% *CI*
All occupied housing units	6.60	5.87	7.33
Northeast	8.73	7.30	10.17
Midwest	7.82	6.01	9.63
South	5.32	4.37	6.28
West	5.55	3.89	7.21
1978–2005	5.62	4.59	6.64
1960–1977	6.35	5.24	7.45
1940–1959	7.04	5.55	8.52
Before 1940	8.65	7.48	9.81
Income ≥$30,000/yr.	7.02	6.14	7.90
Income <$30,000/yr.	5.77	4.93	6.61

[a]*CI* = confidence interval.

TABLE **6**

Maximum Soil Arsenic Levels by Presence or Absence of Wooden Structures in the Yard

Level (parts per million)	% of HUs[a] With Maximum Soil Arsenic > Level	
	Wooden Structures	No Wooden Structures
1	**[97]***	92
5	**[70]***	49
10	**[37]***	21
20	**[16]***	8
40	**[7]***	3
100	1	1

[a]HUs = housing units.
*Statistically significant differences between HUs with wooden structures in the yard and those without such structures (at the 5 level; $p = .05$) shown bolded in square brackets.

Conclusion

Findings provided both evidence of progress and reasons for caution. Positive trends included significant reductions in the percentage of multifamily housing units with LBP hazards, the proportion of housing units with interior dust-lead hazards, and the proportion of housing units with the highest paint-lead levels. To continue recent trends of reduced children's BLLs, proper maintenance in the 37 million housing units with LBP and efforts to identify and address LBP hazards are necessary. On the federal level, U.S. EPA's Renovation, Repair, and Painting (RRP) rule (40 CFR Part 745, especially Subpart E), is expected to reduce the potential for LBP hazards during home renovation. State and local governments can require rental housing to meet minimum maintenance standards (e.g., Maryland requires pre-1978 rental housing to pass a visual inspection and dust test). Outreach efforts to the housing, maintenance, and construction industries and the general public can inform them of ways to prevent children's exposure to lead.

The findings on arsenic levels in soil suggest the need for research to better understand the potential health risk to people who come in contact with the soil, especially in yards with wooden structures that were treated with arsenic-containing compounds.

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