Lead is highly toxic, especially to young children. Excessive exposure causes reduced intelligence, impaired hearing, reduced stature, and many other adverse health effects (NAS 1993). The effects of lead toxicity have been well established, with clear evidence of harm found in children whose blood lead levels are above 10 µg/dL and some evidence that harm may occur at lower levels (CDC 1991; Lanphear et al. 2000; NAS 1993; Schwartz 1994; U.S. EPA 1990). A large body of evidence shows that a common source of lead exposure for children today is lead-based paint hazards in older housing and the contaminated dust and soil it generates (Bornschein et al. 1987; Clark et al. 1991; Jacobs 1995; Lanphear et al. 1995, 1998; Lanphear and Roghmann 1997; McElvaine et al. 1992; Rabinowitz et al. 1985; Shannan and Graef 1992), although other sources can be significant. Poisoning from lead-based paint has affected millions of children since this problem was first recognized more than 100 years ago (Gibson 1904; Turner 1897).

Children are exposed to lead from paint through two major pathways: either directly by eating paint chips (McElvaine et al. 1992) or indirectly by ingesting lead-contaminated house dust or soil through normal hand-to-mouth contact (Bornschein et al. 1987; Duggan and Inskip 1985; Lanphear and Roghmann 1997). Recent studies indicate that dust lead is the strongest predictor of childhood blood lead levels (Duggan and Inskip 1985; Lanphear et al. 1998). Unless proper precautions are implemented, lead-based paint can contaminate dust or soil when it deteriorates or is disturbed during maintenance, repainting, remodeling, demolition, or paint removal (Lanphear and Roghmann 1997; Rabinowitz et al. 1985; Shannan and Graef 1992). Residences with deteriorated lead-based paint are more likely to have higher levels of lead in house dust and the surrounding soil (Jacobs 1995; U.S. EPA 1995; U.S. HUD 1990).

Although lead in new residential paint was banned in the United States in 1978 by the Consumer Product Safety Commission (U.S. CPSC 1977a, 1977b; U.S. HUD 1997), a previous study conducted by the U.S. Department of Housing and Urban Development (HUD) in 1990 showed that lead-based paint still remained in an estimated 64 million dwelling units (U.S. EPA 1995; U.S. HUD 1990).

Recent studies of residential lead hazard controls have evaluated strategies that combined measures to remove and/or repair deteriorated lead-based paint, along with other measures to reduce and prevent reaccumulation of lead in dust. These treatments resulted in substantial and sustained reductions in interior lead dust and children’s blood lead levels (Farfel et al. 1994; Galke et al. 2001; U.S. EPA 1997).

This study is part of the National Survey of Lead and Allergens in Housing and provides recent estimates of lead contamination in U.S. housing. It is part of a study that examines not only lead contamination but also allergen and endotoxin levels in U.S. housing. The allergen and endotoxin survey methodology has been published separately (Vojta et al. 2002).

**Methods**

The target population for this study consisted of the national housing stock of permanently occupied, noninstitutional housing units, including multifamily buildings, single-family housing, and manufactured housing (mobile homes) in all 50 states and the District of Columbia. Vacant housing, group quarters (e.g., prisons, hospitals, dormitories), hotels, motels, and other short-term housing, military bases, and housing where children are not permitted to live (e.g., housing designated exclusively for the elderly and those with zero bedroom units) were excluded. With these excluded, the eligible national housing stock consisted of approximately 96 million housing units out of approximately 112 million units. A nationally representative, random sample of 1,984 housing units was drawn from 75

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**The Prevalence of Lead-Based Paint Hazards in U.S. Housing**

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Table 1. Comparisons of the National Lead-Based Paint Survey population with the American Housing Survey (AHS) and the Current Population Survey (CPS).

| Housing unit characteristic                  | No. estimated (thousands) | National Lead-Based Paint Survey estimates | 95% CI (%) | Housing units in sample |
|----------------------------------------------|---------------------------|-------------------------------------------|------------|------------------------|
| Total housing units                          | 95,688                    | 100                                       | 831        |                        |
| Construction year:                           |                           |                                           |            |                        |
| 1978–1998                                    | 29,774                    | 31                                        | 30–32      | 220                    |
| 1960–1977                                    | 27,874                    | 29                                        | 28–30      | 267                    |
| 1940–1959                                    | 20,564                    | 21                                        | 20–23      | 186                    |
| Before 1940                                  | 17,476                    | 18                                        | 17–20      | 158                    |
| Region                                       |                           |                                           |            |                        |
| Northeast                                    | 19,290                    | 20                                        | 19–22      | 155                    |
| Midwest                                      | 22,083                    | 23                                        | 22–24      | 196                    |
| South                                        | 35,474                    | 37                                        | 36–39      | 277                    |
| West                                         | 18,841                    | 20                                        | 18–21      | 203                    |
| Urbanization:                                |                           |                                           |            |                        |
| MSA ≥ 2 million population                  | 26,814                    | 28                                        | 24–32      | 276                    |
| MSA < 2 million population                  | 45,753                    | 48                                        | 43–53      | 417                    |
| Non-MSA                                      | 23,121                    | 24                                        | 19–30      | 136                    |
| One or more children under age 18           | 35,694                    | 39                                        | 38–39      | 398                    |
| Refusal/don’t know                           | 290                       |                                           | 3          |                        |
| Housing unit type:                           |                           |                                           |            |                        |
| Single family                                | 82,651                    | 86                                        | 84–89      | 705                    |
| Multifamily                                  | 13,037                    | 14                                        | 11–16      | 126                    |
| Tenure                                       |                           |                                           |            |                        |
| Owner occupied                               | 66,222                    | 69                                        | 65–73      | 539                    |
| Renter occupied                              | 29,074                    | 30                                        | 27–34      | 289                    |
| Refusal/don’t know                           | 381                       |                                           | 3          |                        |
| Household income ($30,000)                  |                           |                                           |            |                        |
| <$30,000/year                                | 23,830                    | 35                                        | 30–41      | 309                    |
| ≥ $30,000/year                              | 56,111                    | 59                                        | 54–63      | 482                    |
| Refusal/don’t know                           | 5,747                     |                                           | 40         |                        |
| Household income ($20,000)                  |                           |                                           |            |                        |
| <$20,000/year                                | 19,359                    | 20                                        | 17–24      | 189                    |
| ≥ $20,000–$39,999/year                      | 25,855                    | 27                                        | 23–31      | 228                    |
| ≥ $40,000–$59,999/year                      | 19,316                    | 20                                        | 16–25      | 152                    |
| ≥ $60,000/year                              | 22,890                    | 24                                        | 20–28      | 203                    |
| Refusal/don’t know                           | 8,268                     |                                           | 28         |                        |
| Poverty                                     |                           |                                           |            |                        |
| In poverty                                  | 13,221                    | 14                                        | 11–16      | 137                    |
| Not in poverty                              | 76,336                    | 80                                        | 77–82      | 651                    |
| Refusal/don’t know                           | 6,130                     |                                           | 6          |                        |
| Race                                         |                           |                                           |            |                        |
| White                                        | 77,005                    | 80                                        | 78–83      | 622                    |
| African American                            | 10,365                    | 11                                        | 9–13       | 116                    |
| Other                                        | 6,571                     | 7                                         | 5–8        | 77                     |
| Refusal/don’t know                           | 1,746                     |                                           | 6          |                        |
| Ethnicity                                    |                           |                                           |            |                        |
| Hispanic/Latino                              | 7,434                     | 8                                         | 6–10       | 86                     |
| Not Hispanic/Latino                         | 87,008                    | 91                                        | 88–93      | 736                    |
| Refusal/don’t know                           | 1,246                     |                                           | 9          |                        |

*All percentages are calculated with total housing units (95,688,000) as the denominator; percentages may not total 100% due to rounding. CI = 95% confidence interval for the estimated number or percentage. CPS data were taken from the 1998 CPS for household income and poverty measures and from the 1999 CPS for urbanization and tenure measures. Housing units include permanently occupied, noninstitutional housing units in which children are permitted to live. Refusals and “don’t know” responses by survey respondents.

A stratified sample of four rooms within each unit was drawn according to the following priorities: child’s bedroom, common living area within the unit, kitchen, and one other random room. If no child’s bedroom was present, another bedroom was selected according to a standard protocol. Table 2 presents the type and location of dust and soil samples and paint measurements made in each room, from the building exterior, and in the yard. Soil samples were collected from children’s play areas at 375 housing units in 40 of the original 75 PSUs, and general yard samples were collected in all 75 PSUs. The 40 PSUs were randomly selected from the original 75 PSUs. Play area and yard area soil lead hazards are both included in the estimates of lead-based paint hazards reported here (see definition of “lead-based paint hazard” below). Weights were developed for housing units, rooms, yards, and exterior play yard areas to be nationally representative.

A standardized questionnaire was administered to an adult resident in each unit to determine age and renovation history of the unit; occupants’ age, race and ethnic group, occupation, hobbies, and smoking patterns; income; and education. The CPS data were taken from the 1998 CPS for household income and poverty measures and from the 1999 CPS for urbanization and tenure measures.
Table 2. Location and type of sample collected.

| Rooms and sample type                        | Yard/play areas | Walls | Ceilings | Windows | Doors | Other trim | Floors |
|----------------------------------------------|-----------------|-------|----------|---------|-------|------------|--------|
| Kitchen                                      |                 | X     | X        | X       | X     | X          |        |
| Lead dust                                    |                 |       |          |         |       |            |        |
| Paint                                        |                 |       |          |         |       |            |        |
| Living room/family room                      |                 | X     | X        | X       | X     | X          |        |
| Lead dust                                    |                 |       |          |         |       |            |        |
| Paint                                        |                 |       |          |         |       |            |        |
| Bedroom(s)                                   |                 | X     |          | X       | X     | X          |        |
| Lead dust                                    |                 |       |          |         |       |            |        |
| Paint                                        |                 |       |          |         |       |            |        |
| Other random room(s)                         |                 | X     | X        | X       | X     | X          |        |
| Lead dust                                    |                 |       |          |         |       |            |        |
| Paint                                        |                 |       |          |         |       |            |        |
| Major entrance                               |                 |       |          |         |       |            |        |
| Lead dust                                    |                 |       |          |         |       |            |        |
| Interior common area ( multifamily only       |                 |       |          |         |       |            |        |
| Lead dust                                    |                 |       |          |         |       |            |        |
| Exterior                                     |                 |       |          |         |       |            |        |
| Paint                                        |                 |       |          |         |       |            |        |
| Soil                                         | X               |       |          |         |       |            |        |

Table 3. Paint testing locations.

| Interior paint testing per room              | Exterior paint testing |
|----------------------------------------------|------------------------|
| Wall—all four major walls                    | Siding—all four walls  |
| Ceiling                                      | Trim—two miscellaneous, one random wall |
| Door and related trim (if present)           | Window and related trim—one random wall |
| Window and related trim (if present)         | Door of major entrance to building |
| Baseboard                                    | Porch and railing       |
| Floor                                        | Surfaces with deteriorated paint |

Table 4. Type of lead-based paint hazard.

| Type of hazard                               | No. housing units (thousands) | Percent housing units |
|----------------------------------------------|------------------------------|-----------------------|
|                                              | Estimate 95% CI              | Estimate 95% CI       |
| Significantly deteriorated lead-based paint  | 13,624; 10,928–16,341        | 14; 11–17             |
| Intermediate lead-contaminated dust          | 15,468; 12,982–17,954        | 16; 14–19             |
| Lead-contaminated soil                       | 6,460; 3,122–9,799           | 7; 3–10               |
| Any significant lead-based paint hazard      | 24,026; 21,306–26,746        | 25; 22–28             |
| Any lead-based paint                         | 37,897; 34,521–41,272        | 40; 36–43             |

*All percentages are calculated with total housing units (95,688,000) as the denominator; percentages may not total 100% due to rounding.
with units built between 1960 and 1978. Approximately 36% of the housing in the Northeast and Midwest had lead-based paint hazards, compared with about 16% of housing in the South and West. Surprisingly, units in large urban and small urban and rural areas had roughly the same prevalence of lead-based paint hazards (~27%).

Rental units also had a slightly higher prevalence of lead-based paint hazards compared with owner-occupied units (30% and 23%, respectively).

This study also examined for the first time the prevalence of lead-based paint hazards in housing built after lead paint was banned in 1978. Among housing built between 1978 and 1998, 3% (1,042,000 housing units) had significant lead-based paint hazards, but 7% (2,031,000 housing units) may have had lead-based paint. (More than half of the XRF measurements above 1.0 mg/cm² in these newer units were on painted tile or stone substrates and are therefore uncertain because the lead may be in the substrates themselves, not the paint.)

Table 5. Prevalence of significant lead-based paint hazards in housing units (number and percent).a

| Characteristics            | All housing units (thousands) | Units with hazards | 95% CI | Percent housing units | No. housing units in sample |
|----------------------------|-------------------------------|-------------------|-------|-----------------------|-----------------------------|
|                            | No. housing units | Units with hazards | Units with hazards | No. housing units in sample |
| Total occupied housing units | 95,688 | 24,026 | 21,306–26,746 | 25 | 22–28 | 831 |
| Region                     |                   |                   |       |                       |                             |
| Northeast                  | 19,290 | 7,679 | 5,748–9,611 | 40 | 30–50 | 155 |
| Midwest                    | 22,083 | 7,250 | 6,402–8,097 | 33 | 29–37 | 196 |
| South                      | 35,474 | 6,191 | 4,964–7,419 | 17 | 14–21 | 277 |
| West                       | 18,841 | 2,906 | 1,856–3,956 | 15 | 10–21 | 203 |
| Construction year          |                   |                   |       |                       |                             |
| 1978–1998                  | 29,774 | 1,042 | 169–1,915 | 3 | 1–6 | 220 |
| 1960–1967                  | 27,874 | 2,340 | 1,440–3,235 | 8 | 6–12 | 267 |
| 1940–1959                  | 20,564 | 8,826 | 6,720–10,933 | 43 | 32–51 | 186 |
| Before 1940                | 17,476 | 11,818 | 10,045–13,591 | 68 | 56–75 | 158 |
| One or more children < 6 years old |       |       |       |                       |                             |
| All housing units          | 16,402 | 4,155 | 2,948–5,363 | 25 | 18–33 | 184 |
| Units built 1978–1998      | 5,847 | 158 | 59–267 | <1 | — | 56 |
| Units built 1960–1977      | 5,098 | 469 | 0–940 | 9 | 0–18 | 61 |
| Units built 1940–1959      | 3,055 | 1,732 | 1,088–2,375 | 57 | 36–78 | 40 |
| Units built before 1940    | 2,401 | 1,955 | 1,190–2,720 | 81 | 50–113 | 27 |
| Urbanization               |                   |                   |       |                       |                             |
| MSA ≥ 2 million population | 26,814 | 6,793 | 4,978–8,609 | 25 | 19–32 | 276 |
| MSA < 2 million population | 45,753 | 10,232 | 8,171–12,293 | 22 | 18–27 | 417 |
| Non-MSA                    | 23,121 | 7,001 | 3,848–10,153 | 30 | 17–44 | 138 |
| Housing unit type          |                   |                   |       |                       |                             |
| Single family              | 82,651 | 21,584 | 18,974–24,194 | 26 | 23–29 | 705 |
| Multifamily                | 13,037 | 2,442 | 1,208–3,676 | 19 | 9–28 | 126 |
| Occupant status            |                   |                   |       |                       |                             |
| Owner occupied             | 62,232 | 15,305 | 13,191–17,419 | 23 | 20–26 | 539 |
| Renter occupied            | 29,074 | 8,721 | 6,583–10,859 | 30 | 23–37 | 289 |
| Refusal/don’t know         | 981 | — | — | 3 | — | 3 |
| Household income           |                   |                   |       |                       |                             |
| < $30,000/year             | 33,830 | 12,007 | 9,336–14,679 | 35 | 28–43 | 309 |
| ≥ $30,000/year             | 56,111 | 10,464 | 8,250–12,678 | 19 | 15–23 | 482 |
| Refusal/don’t know         | 5,747 | — | — | 40 | — | 40 |
| One or more children < 6 years old |       |       |       |                       |                             |
| All income categories      | 16,402 | 4,155 | 2,948–5,363 | 25 | 18–33 | 184 |
| < $30,000/year             | 4,791 | 1,201 | 600–1,801 | 25 | 13–38 | 61 |
| ≥ $30,000/year             | 11,236 | 2,860 | 1,763–3,957 | 25 | 16–35 | 117 |
| Refusal/don’t know         | 375 | — | — | 6 | — | 6 |
| Government support         |                   |                   |       |                       |                             |
| Government support         | 4,809 | 805 | 275–1,335 | 17 | 6–28 | 54 |
| No government support      | 86,070 | 22,198 | 19,252–25,144 | 26 | 22–29 | 733 |
| Refusal/don’t know         | 4,809 | — | — | 44 | — | 44 |
| Poverty                    |                   |                   |       |                       |                             |
| In poverty                 | 13,221 | 4,976 | 3,458–6,494 | 38 | 26–49 | 137 |
| Not in poverty             | 76,336 | 16,576 | 13,598–19,555 | 22 | 18–26 | 651 |
| Refusal/don’t know         | 6,130 | — | — | 43 | — | 43 |
| Race                       |                   |                   |       |                       |                             |
| White                      | 77,005 | 19,089 | 16,475–21,703 | 25 | 21–28 | 622 |
| African American           | 10,365 | 2,969 | 1,807–4,131 | 29 | 17–40 | 116 |
| Otherf                     | 6,571 | 1,496 | 672–2,321 | 23 | 10–35 | 77 |
| Refusal/don’t know         | 1,746 | — | — | 16 | — | 16 |
| Ethnicity                  |                   |                   |       |                       |                             |
| Hispanic/Latino            | 7,434 | 2,399 | 1,235–3,564 | 32 | 17–48 | 86 |
| Not Hispanic/Latino        | 87,008 | 21,196 | 18,674–23,719 | 24 | 21–27 | 736 |
| Refusal/don’t know         | 1,246 | — | — | 9 | — | 9 |

*aSignificant lead-based paint hazard means a lead-based paint hazard above de minimis levels as defined in U.S. EPA and U.S. HUD regulations (U.S. EPA 2001; U.S. HUD 1999). The de minimis levels for paint deterioration are ≤ 20 ft² (exterior) or ≤ 2 ft² (interior) of lead-based paint on large surface area components (walls, doors), or damage to ≤ 10% of the total surface area of interior small surface area components (windowsills, baseboards, trim). All percentages are calculated with total housing units (95,888,000) as the denominator; percentages may not total 100% due to rounding. CI = 95% confidence interval for the estimated number or percentage. All percentages are calculated with the “All housing units” column in each row used as the denominator. No 1978–1998 housing units with one or more children < 6 years old in this sample have lead-based paint hazards. upper 95%CI value > 100% reflects uncertainty in number of housing units in first data column. Refusals and “don’t know” responses by survey respondents. Other race includes Asian, American Indian or Alaskan Native, Native Hawaiian or other Pacific Islander, and more than one race.
lead level for floors, window sils, and window troughs was 1.1 µg/ft², 9.4 µg/ft², and 96.4 µg/ft², respectively (Table 6). The arithmetic means (used for composite dust sampling) for these surfaces were 13.6 µg/ft², 195 µg/ft², and 1,991 µg/ft², respectively. These can be compared with the current U.S. EPA/HUD dust lead hazard or clearance standards for these surfaces, which are 40 µg/ft², 250 µg/ft², and 400 µg/ft², respectively (U.S. EPA 2001; U.S. HUD 1999).

Dust lead hazards are more likely to exist in homes with significantly deteriorated interior lead-based paint. Although only one-third of homes with interior lead-based paint in good condition had dust lead hazards, nearly two-thirds of the homes with deteriorated interior lead-based paint had dust lead hazards (Table 7). Based on our results, of the 24 million units with lead-based paint hazards, 2.7 million units with lead-based paint on either the interior or exterior at the time of the survey have dust lead hazards. Of the 2.7 million housing units with dust lead hazards but no intact or deteriorated lead-based paint, approximately 270,000 units had soil lead hazards, and occupants in another 700,000 units reported having a lead hobby or an occupation potentially using lead, all of which can contribute to interior dust lead levels.

**Bare soil lead hazards.** An estimated 5% (~4.9 million) of housing units nationwide had play area soil lead levels ≥ 400 ppm, the current U.S. EPA/HUD standard (U.S. EPA 2001; U.S. HUD 1999) (Table 8). Among all housing unit yard areas, 7% (~6.3 million) have bare soil lead levels ≥ 1,200 ppm, the current U.S. EPA/HUD standard outside of play areas (U.S. EPA 2001; U.S. HUD 1999) (Table 9). Soil lead levels are also related to deteriorated exterior lead-based paint. Comparing units with and without deteriorated exterior lead-based paint, the percentage of units with bare soil lead levels ≥ 1,200 ppm decreases from 24% to only 4%, respectively (Table 10).

**Lead-based paint.** Our results indicate that 38 million units have lead-based paint somewhere in the interior or on the exterior of the unit (Table 4). The influences of age, demographic, and socioeconomic factors on the presence of lead-based paint are similar to those presented in Table 5 for significant lead-based paint hazards. Although 40% of housing units had lead-based paint somewhere, most surfaces, even in older housing stock, did not have lead-based paint (Table 11). In post-1960 housing, only 0–2% of interior surfaces had lead-based paint, whereas 0–12% of exterior surfaces had lead-based paint. Even in older pre-1940 housing, only 7–22% of interior surfaces and 24–41% of exterior surfaces had lead-based paint. In almost all age categories for both interior and exterior surfaces, the building components with the highest prevalence of lead-based paint were windows and doors. These are friction and impact surfaces that can generate significant levels of lead dust and paint chips.

For all housing units, we estimate 7.5 billion ft² of interior lead-based paint and 29.2 billion ft² on exterior surfaces, roughly 2% and 22% of the total interior and exterior painted surfaces, respectively. On average, for each housing unit with lead-based paint, there are 259 ft² of lead-based paint on interior surfaces and 996 ft² on exterior surfaces (Table 12).

A comparison of the 1990 HUD survey (U.S. EPA 1995; U.S. HUD 1990) with this study shows that the number of units with lead-based paint fell from 64 million units in 1990 to 38 million in 2000 (Tables 4 and 13). Some possible reasons for this decline are discussed below.

**Discussion**

The results show that despite considerable progress, significant lead-based paint hazards remain prevalent, existing in 25% of all U.S. housing. The association between lead-based

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**Table 6. Dust lead loadings on floors and windows.**

| Statistic | Floors (µg/ft²) | Windowsills (µg/ft²) | Window troughs (µg/ft²) |
|-----------|----------------|----------------------|------------------------|
| Arithmetic mean | 13.6 | 194.9 | 1,990.9 |
| Arithmetic SD | 483.5 | 1,682.7 | 12,086.5 |
| Geometric mean | 1.1 | 9.4 | 98.4 |
| Geometric SD | 3.8 | 9.3 | 14.4 |
| 25th percentile | 0.375 | 2.0 | 18.0 |
| Median | 0.9 | 8.3 | 89.1 |
| 75th percentile | 2.0 | 37.13 | 462.0 |
| 90th percentile | 6.0 | 172.8 | 2,824.2 |
| 95th percentile | 13.2 | 524.9 | 6,974.6 |
| HUD/EPA standards | 40 | ≥2,000 ppm | NA |
| No. samples | 3,894 | 2,302 | 1,607 |

**Table 7. Association between dust lead hazards and presence and condition of interior lead-based paint (all housing unit ages, thousands of units).**

| Characteristic | No lead-based paint on interior or exterior | No interior lead-based paint a | No interior lead-based paint in good condition | Significantly deteriorated interior lead-based paint | Statistic Floors (µg/ft²) | Windowsills (µg/ft²) | Window troughs (µg/ft²) |
|---------------|-------------------------------------------|-------------------------------|-----------------------------------------------|-----------------------------------------------|-------------------------|-----------------------|------------------------|
| No interior dust lead hazards | 55,105 | 95 | 62,752 | 94 | 15,244 | 67 | 2,389 | 39 |
| Lower 95% CI | 51,893 | 90 | 60,141 | 90 | 12,833 | 56 | 1,565 | 26 |
| Upper 95% CI | 59,318 | 100 | 65,363 | 98 | 17,055 | 78 | 3,213 | 53 |
| Interior dust lead hazards | 2,686 | 5 | 4,068 | 6 | 7,508 | 33 | 3,727 | 61 |
| Lower 95% CI | 1,372 | 2 | 2,584 | 4 | 6,024 | 26 | 2,505 | 41 |
| Upper 95% CI | 4,001 | 7 | 5,552 | 8 | 8,992 | 40 | 4,949 | 81 |
| Total housing units | 57,791 | 100 | 66,820 | 100 | 22,752 | 100 | 6,116 | 100 |

**Table 8. Distribution of bare soil lead concentrations in children’s play areas.**

| Bare play area soil lead levels (ppm) | No. housing units (thousands) a | Percent housing units a | Housing units (n) |
|--------------------------------------|-------------------------------|------------------------|-------------------|
| ≥ 0 | 76,404 | 69,826–82,962 | 80 | 73–87 | 294 |
| ≥ 20 | 49,019 | 42,946–55,092 | 51 | 45–58 | 209 |
| ≥ 50 | 28,878 | 25,828–31,929 | 30 | 27–33 | 127 |
| ≤ 200 | 10,849 | 7,899–13,800 | 11 | 8–14 | 101 |
| ≤ 400 | 4,856 | 2,096–7,616 | 5 | 2–8 | 84 |
| ≥ 1,200 | 2,403 | 458–4,529 | 3 | 1–5 | 82 |
| ≥ 1,600 | 2,078 | 92–4,063 | 2 | 0–4 | 80 |
| ≥ 2,000 | 1,777 | 0–3,871 | 2 | 0–4 | 77 |
| ≥ 5,000 | 380 | 0–1,231 | 0 | 0–1 | 1 |
| No play area | 12,368 | 6,659–18,077 | 13 | 7–19 | 53 |
| Missing b | 8,916 | 1,146–10,879 | 7 | 0–13 | 23 |
| Total | 95,688 | 100 | 270,000 | 100 | 3,750 |

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*All percentages are calculated with total housing units (95,688,000) as the denominator; percentages may not total 100% due to rounding. All percentages are calculated with total housing units (95,688,000) as the denominator. *U.S. EPA standard for play areas. *Missing means that soil was present but no lead value is available (usually due to inaccessibility or respondent refusal).
paint, lead-contaminated dust, and lead-contaminated soil is consistent with the 1990 HUD survey. Yet 2.7 million homes without lead-based paint had dust lead hazards at the time of the recent survey. However, the fact that lead-based paint was not found in these homes at the time of the survey does not necessarily mean it had never been present at some time in the past. Ongoing housing rehabilitation, maintenance, and repainting all tend to remove lead-based painted surfaces but may leave behind dust lead hazards. Also, some lead-contaminated dust may be from lead-contaminated soil tracked into homes. Although some dust lead may be due to aerosol deposition from ambient air, air lead levels in the United States have declined greatly with the phaseout of leaded gasoline. It is also possible that lead-contaminated dust can originate from lead-based paint in nearby dwellings that are undergoing rehabilitation, maintenance, or repainting. Additionally, some of the lead hobbies or occupations reported by occupants could produce a lead dust hazard. In any case, Table 7 shows that the vast majority of houses with dust lead hazards have lead-based paint on either the interior or exterior, and that houses with deteriorated lead-based paint are far more likely to have dust lead hazards. Further research is needed to identify other potential sources of dust lead hazards.

The apparent decrease in the number of units with lead-based paint over the past decade was greater than expected, declining from about 64 million (or 83%) of pre-1980 housing units to 38 million (or 40%) of all 96 million housing units in the sampling frame of this study, a decline of 26 million units. A number of factors that likely contributed to this apparent decline are discussed below.

**Ongoing lead hazard control activities.**

The number of units undergoing lead hazard control likely increased over the past decade because of HUD’s lead hazard control grants to local governments; other similar local, state, and federal lead hazard control programs; lead hazard control requirements in HUD’s public housing program and federally assisted housing programs; promulgation and enforcement of the U.S. EPA/HUD lead-based paint disclosure regulation (U.S. HUD and U.S. EPA 1996); and increased public awareness of lead-based paint hazards, which likely resulted in privately funded lead hazard control activities. The effect of public education (carried out largely through federal, state, and local programs) in prompting lead hazard control efforts is difficult to quantify but may be much larger than is currently understood.

**Demolition and renovation.**

Although demolition, remodeling, and renovation activities are known to increase exposures in the short run if lead-safe work practices are not used, they reduce both the number of units and the number of surfaces within units with lead-based paint over the long run. Over the past 5 years, standardized curricula and training courses have been developed to educate the work force on lead-safe work practices, and the U.S. EPA has promulgated a final rule regarding public education prior to certain renovation practices (U.S. EPA 1998). This educational effort should reduce the generation of lead-contaminated dust during renovation and maintenance.

It is widely assumed that the phaseout of lead in gasoline and lead in food canning are primarily responsible for most of the decline in population blood lead levels over the past several decades (along with regulation of lead in water and industrial emissions). But it is likely that housing rehabilitation, maintenance, and demolition also had a significant impact over the same time period. The President’s Task Force on Environmental Health Risks and Safety to Children (2000) used data from the American Housing Survey and other sources to estimate the size of this effect during the 1990s. Those data show that older units with lead-based paint are more likely to undergo rehabilitation or demolition than are newer houses. From 1989 to 1999, the number of pre-1940 units declined by 2.8% annually, the number of 1940–1959 units declined by 2.65% annually, and those from 1960–1974 declined by 2.1% annually. In short, from 1989 to 1999, the number of units with lead-based paint declined by a total of about 10 million units due to housing demolition and renovation alone (Appendix to the President’s Task Force Report 2000). This same pattern likely occurred during earlier decades as well, contributing to the overall decline in population blood lead levels in ways not previously recognized.

**Improvements in laboratory and XRF technology and quality control.**

This study used an XRF model that is both more precise and more

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**Table 9. Distribution of bare soil lead concentration in entire yard by construction year.**

| Bare soil lead concentration (ppm) | Number of housing units (thousands) | Percent housing units |
|----------------------------------|------------------------------------|-----------------------|
|                                  | All Before 1940–1959 | 1960–1974 | 1978–1988 | 1988–1999 | All Before 1940–1959 | 1960–1974 | 1978–1988 | 1988–1999 |
|                                  | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| ≥ 0 | 77,888 | 12,015 | 16,843 | 23,185 | 25,845 | 81 | 69 | 82 | 83 | 87
| ≥ 20 | 55,114 | 12,015 | 15,404 | 17,345 | 10,350 | 58 | 69 | 75 | 62 | 35
| ≥ 50 | 40,023 | 11,193 | 12,789 | 10,437 | 5,603 | 42 | 64 | 62 | 37 | 19
| ≥ 200 | 16,579 | 7,243 | 6,073 | 1,793 | 190 | 16 | 41 | 30 | 6 | 1
| ≥ 400 | 9,958 | 5,148 | 3,736 | 1,111 | 0 | 10 | 30 | 18 | 4 | 0
| ≥ 1,200 | 6,271 | 3,398 | 2,886 | 0 | 0 | 7 | 19 | 14 | 0 | 0
| ≥ 1,600 | 3,900 | 2,006 | 1,894 | 0 | 0 | 4 | 12 | 9 | 0 | 0
| ≥ 2,000 | 3,124 | 1,320 | 1,804 | 0 | 0 | 3 | 8 | 9 | 0 | 0
| ≥ 5,000 | 1,580 | 1,106 | 475 | 0 | 0 | 2 | 6 | 2 | 0 | 0
| Missing | 145 | 145 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0
| No soil | 15,413 | 4,313 | 2,762 | 4,613 | 3,724 | 16 | 25 | 13 | 17 | 13
| No soil | 2,242 | 1,003 | 939 | 95 | 205 | 2 | 6 | 5 | 0 | 1
| Total | 95,688 | 17,476 | 21,544 | 27,893 | 29,774 | 100 | 100 | 100 | 100 | 100

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**Table 10. Association between bare soil lead concentration and housing units with or without deteriorated exterior lead-based paint.**

| Bare soil lead concentration (ppm) | Without any lead-based paint | With significantly deteriorated exterior lead-based paint |
|-----------------------------------|-----------------------------|---------------------------------------------------------|
| Percent | 95% CI | Percent | 95% CI | Percent | 95% CI |
| ≥ 0 | 83 | 78–88 | 83 | 77–88 | 73 | 55–92 |
| ≥ 20 | 49 | 41–56 | 36 | 30–47 | 67 | 51–83 |
| ≥ 50 | 26 | 20–30 | 13 | 9–17 | 39 | 29–58 |
| ≥ 200 | 5 | 1–5 | 8 | 5–11 | 30 | 11–49 |
| ≥ 400 | 3 | 0–5 | 4 | 2–7 | 24 | 7–41 |
| ≥ 1,200 | 1 | 0–3 | 2 | 1–4 | 17 | 4–30 |
| ≥ 1,600 | 1 | 0–2 | 2 | 0–4 | 13 | 2–24 |
| ≥ 2,000 | 0 | 0–0 | 0 | 0–0 | 8 | 0–17 |
| Missing | 0 | 0–0 | 0 | 0–0 | 1 | 0–5 |
| No soil | 14 | 10–19 | 15 | 11–20 | 22 | 3–41 |
| No soil | 3 | 0–2 | 2 | 0–4 | 4 | 0–9 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 |
accurate than the instrument used in 1990 (U.S. HUD 1990). Over the past decade, Performance Characteristics Sheets defining acceptable tolerance limits for all commercially available instruments have been published (U.S. HUD 1997), which has spurred the introduction of a new generation of more precise and accurate lead-based paint analyzers, one of which was used in this study. In addition, all states now have certification (licensing) laws (or are covered by the U.S. EPA) for lead-based paint inspectors (U.S. EPA 1996); in 1990, only one state had such a law. All of this makes it less likely to misclassify a surface with lead-based paint in the more recent survey.

Larger sample size. The recent study sampled more units (831 vs. 284), more rooms within units (4–6 rooms vs. 2 rooms), and completed more measurements within rooms, compared to the 1990 survey (U.S. HUD 1990), making these estimates more precise and accurate. The larger number of measurements would be expected to increase the number of homes with lead-based paint, contrary to the findings above, if the number of units with lead-based paint in fact had remained the same. There may be other methodologic differences in the two surveys that could explain some of the observed decline, which will be explored in future papers.

Other key findings. Differences in the definition of what constitutes a lead-based paint hazard and the protocols to measure lead in dust and soil changed greatly between the two surveys, making a direct comparison of hazard prevalence problematic. The percentage of housing units with deteriorated lead-based paint actually increased slightly, from 19% in 1990 to 22% in the present study (Table 13). Although the difference did not reach statistical significance, such an increase could reflect continued aging of the housing stock and changes in the definition of paint deterioration used in the two studies. If the prevalence of deteriorated paint either increased or remained constant over the past decade, additional efforts are needed to maintain lead-based paint in a way that ensures that it does not deteriorate and present new hazards.

This study shows that most painted surfaces, even in older housing, are not coated with lead-based paint. Use of lead-safe work practices on surfaces with lead-based paint is essential in order to minimize dust, paint chips, and contaminated soil that may be generated during maintenance and housing rehabilitation activities, because only a small amount of lead-based paint is needed to produce very high dust lead levels. For example, if sanded and turned into contaminated dust that is spread across an average-size room, only 1 ft² of paint at a lead concentration of 1 mg/cm² (the federal standard) is needed to produce a settled dust lead level of 9,300 µg/ft², several orders of magnitude above current dust lead standards (U.S. HUD 1995).

This study also suggests that rental properties are somewhat more likely to have lead-based paint hazards than are owner-occupied properties (30% vs. 23%, respectively), perhaps because of the increased turnover rates and lower maintenance levels that may be more common in rental units. Thus, efforts to increase homeownership may also serve to reduce the prevalence of childhood lead poisoning.

Although it has been widely assumed that large cities have a higher prevalence of lead-based paint hazards than do smaller ones, these data show that urban and rural areas both have roughly the same prevalence—about 26% (Table 5). These results suggest that greater attention may need to be given to rural housing, although large cities clearly have more units with lead-based paint hazards within relatively small geographic areas.

The percentage of building components coated with lead-based paint in housing built after the 1978 ban is 0–3% (Table 11). This suggests that the ban was not immediately effective in removing stocks of lead-based paint from retail and wholesale outlets. It also suggests that there may be continuing use of industrial or marine lead-based paint, which is still available, in housing. The fact that about half of the XRF readings indicating a lead concentration greater than 1 mg/cm² were taken on tiled surfaces means that the percentage of surfaces with lead-based paint in newer housing is between 1% and 2%. It is not known whether lead was actually present in the tile itself or in the glazing of the tile, or

Table 11. Building components coated with lead-based paint by year of construction (%).

| Component type          | All years | 1978–1998 | 1960–1977 | 1940–1959 | Before 1940 |
|-------------------------|-----------|-----------|-----------|-----------|-------------|
| Interior                |           |           |           |           |             |
| Walls, floors, ceilings | 2         | 0         | 1         | 2         | 7           |
| Windows                 | 9         | 1         | 2         | 6         | 21          |
| Doors                   | 7         | 0         | 1         | 7         | 22          |
| Trim                    | 5         | 0         | 2         | 4         | 15          |
| Other                   | 4         | 0         | 1         | 2         | 12          |
| Exterior                |           |           |           |           |             |
| Walls                   | 14        | 0         | 9         | 18        | 34          |
| Windows                 | 25        | 0         | 12        | 30        | 41          |
| Doors                   | 15        | 2         | 5         | 29        | 33          |
| Trim                    | 11        | 3         | 8         | 16        | 24          |
| Porch                   | 15        | 1         | 7         | 25        | 28          |
| Other                   | 18        | 0         | 8         | 37        | 37          |

Table 12. Surface area of lead-based paint.

| Component           | National total surface area of lead-based paint | Avg surface area per housing unit (ft²) |
|---------------------|-----------------------------------------------|----------------------------------------|
|                     | Square feet (billions) | Paint on component (%) |                                      |
| Interior            |                               |                                      |                                      |
| Wall, floor, ceiling| 4,993                         | 2                                     | 173                                   |
| Window              | 687                           | 9                                     | 24                                    |
| Door                | 911                           | 6                                     | 32                                    |
| Trim                | 499                           | 5                                     | 17                                    |
| Cabinets, chimney, beams | 388                      | 2                                     | 13                                    |
| Total               | 7,448                         | 2                                     | 259                                   |
| Exterior            |                               |                                      |                                      |
| Wall                | 26,706                        | 18                                    | 912                                   |
| Window              | 365                           | 28                                    | 12                                    |
| Door                | 446                           | 14                                    | 15                                    |
| Trim                | 556                           | 12                                    | 19                                    |
| Porch               | 1,086                         | 21                                    | 37                                    |
| Total               | 29,159                        | 22                                    | 986                                   |

Avg, average.

Table 13. Comparison of the prevalence of lead-based paint to that in the 1990 HUD survey (housing units built before 1980).

| Location and condition of lead-based paint | 1990 HUD survey | 2000 HUD national survey |
|------------------------------------------|-----------------|--------------------------|
|                                          | No.             | Percent                  | No.             | Percent                  |
| Housing units built before 1980           | 77,177          | 100                      | 68,756          | 100                      |
| Units with lead-based paint              | 64,059          | 83                       | 34,195          | 50                       |
| Interior lead-based paint                | 48,988          | 63                       | 26,184          | 39                       |
| Exterior lead-based paint                | 56,495          | 73                       | 27,373          | 40                       |
| Units with deteriorated lead-based paint  | 14,354          | 19                       | 14,962          | 22                       |
| Interior deteriorated lead-based paint   | 5,596           | 7                        | 7,281           | 11                       |
| Exterior deteriorated lead-based paint   | 9,057           | 13                       | 11,784          | 17                       |

*Deteriorated lead-based paint is as defined in U.S. HUD (1995). *AAll the data in this table are restricted to housing built before 1980. *Thousands of housing units.
whether it was an instrumentation artifact. Furthermore, it is not known whether tile poses a significant source of lead exposure to children. Further analyses of the prospect of continuing contamination of U.S. housing through new application of lead-based paint and the nature and importance of lead in tile are both needed. Nevertheless, it is clear that lead-based paint hazards in housing built after 1978 are very rare.

**Conclusion**

This study shows that despite a large decline in the number of housing units with lead-based paint from 1990 to 2000, there are still millions remaining with hazards. Resources should be directed to those most likely to cause childhood lead poisoning: older housing units with lead-based paint hazards that are occupied by (or likely to be occupied by) children under 6 years of age and are low-income and/or are undergoing certain housing rehabilitation or maintenance that disturbs surfaces coated with lead-based paint. Hazard controls should focus on deteriorated lead-based paint, windows, doors, dust, and bare soil in play areas. Window replacement also has other important benefits, such as energy conservation.

This study confirms a prediction released by the President's Task Force in February 2000. That forecast indicated that based on trends in demolition, housing rehabilitation, lead hazard control, and other factors, the number of units with lead-based paint hazards in 1999 could be expected to be 24 million. This study found that the actual number is 24 ± 2.7 million units, making the task force estimate well within the confidence interval of this survey. The task force report indicated that private and public expenditures for the incremental cost of lead hazard control totaling approximately $230 million per year for 10 years would be needed to virtually eliminate childhood lead-based paint poisoning and realign a net benefit of $890 million per year for 10 years from avoided childhood lead-poisoning cases. This cost analysis factors in ongoing housing rehabilitation, maintenance, and lead hazard control, as well as regulation of federally assisted low-income housing. Further efforts are needed to improve maintenance standards by incorporating lead-safe work practices into routine housing operations, especially in low-income housing.

Further efforts are also needed to educate maintenance and housing rehabilitation workers, property owners, parents, and others to help ensure that lead-based paint remaining in millions of houses does not become hazardous and pose future risks to millions of children born into or occupying such houses in the coming decades.

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