# Lead Particulate Deposition from Housing Demolition

David E. Jacobs, PhD, CIH,[1, 2] Bogdan Catalin,[2] Alison Welch,[2] Amy P. Mucha, PhD,[2] Nicole Stites,[4] Sherry Dixon, PhD,[1] Anne Evens,[2] Patrick MacRoy,[4] Serap Erdal, PhD, MSc,[2] Victoria Persky, MD,[2] Janet Phoenix, MD, MPH,[3] Salvatore Cali, CIH[2]

[1] National Center for Healthy Housing, Washington, DC, United States
[2] University of Illinois at Chicago, Chicago, Illinois, United States
[3] George Washington University, Washington, DC, United States
[4] Chicago Department of Public Health, Chicago, IL, United States

*Email:dejacobs@starpower.net*

**Summary**

This study characterized lead dustfall from demolition of single- and multifamily housing likely to contain lead-based paint in two US cities. In Chicago, 67 scattered single family houses were demolished with minimal or nominal dust suppression methods. In Baltimore, approximately 500 contiguous multifamily row houses were demolished using barriers, continuous water spraying, containment, and deconstruction. Lead dustfall was measured by APHA Method 502 and US EPA Methods SW3050B and SW6020. Although far more demolitions within a smaller area over a shorter time period were done in Baltimore, lead dustfall was much lower than in Chicago. The geometric mean lead dustfall during demolition in Chicago was 29.6 µg Pb/m$^2$/hr (range: <1-32,010 µg Pb/m$^2$/hr), while in Baltimore it was only 9.2 µg Pb/m$^2$/hr (range: <4.7-258 µg Pb/m$^2$/hr. Large amounts of lead-contaminated dust are generated from housing demolition, but can be controlled using simple dust suppression to protect the public health.

**Keywords –** Healthy Housing 2008, lead poisoning, housing demolition, lead dust, dust suppression

## Introduction

Despite substantial progress, childhood lead poisoning remains a major problem in the U.S., with 310,000 children having blood lead levels greater than 10 µg/dL between 1999-2002 (CDC 2005). Globally, lead exposure ranks 19$^{th}$ in disability adjusted life years (WHO 2003). Older housing with lead-based paint is known to be a major source of exposure, following the elimination of lead from food canning, gasoline, new paint and other sources in the U.S. (Jacobs 1995), Europe (WHO 2006) and elsewhere. Recently, there have been reports of the production of new lead-based paint in Asia and Africa, threatening the progress that has been made in Western countries and posing an emerging problem in Asian and African housing (Clark et al. 2006; Adebamowo et al. 2007).

Demolition of older housing units containing lead-based paint is proceeding at a rapid pace in many urban areas. For example, over 3,000 units are demolished annually in Chicago. Previous work (Farfel et al. 2003; Farfel et al. 2005) demonstrated that multifamily housing demolition can produce settled dust lead levels on exterior surfaces that greatly exceed U.S. Environmental Protection Agency (EPA) standards for interior floors. The present study is the first to characterize lead dustfall from single family housing demolition. We also compare these results to lead dustfall from a recent multifamily housing demolition project where modern extensive dust suppression and demolition protocols were employed.

Demolition of older housing in the US has been shown to explain approximately 30% of the reduction in children's blood lead levels over a 20 year time period (Jacobs and Nevin 2006), because over the long run, lead contaminated housing is removed from service. But demolition could also contribute to short term exposures due to exposure to lead-contaminated dust.

Furthermore, dust emissions from housing demolition may also contribute to diseases other than lead poisoning, such as asthma. A previous study of demolition of large public housing structures found that enough particulate matter was released to potentially trigger asthmatic symptoms (Dorevitch et al. 2006).

A national survey of the US housing stock shows that there are approximately 7.4 billion square feet of interior surfaces and 29.2 billion square feet of exterior surfaces coated with lead paint ≥ 1 mg/cm$^2$ (Vojta et al. 2002). The potential impact of disturbing this large surface area of lead-based paint is substantial, as demonstrated by the following example: If a painted surface area of one square foot at 1 mg/cm$^2$ of lead is disturbed and turned into dust, and if that dust is evenly distributed over an average 10 foot x 10 foot room floor, the resulting lead loading will be 9,300 µg/ft$^2$, well above the existing EPA limit of 40 µg/ft$^2$ (EPA 2001).

While lead standards have been developed for paint, interior settled dust and bare soil (EPA 2001) as well as ambient air and drinking water, no standard has been developed for exterior settled dust, despite the fact that it is known to be correlated with interior dust lead and children's blood lead levels (NCHH 2004). While there is a cleanup guideline from the U.S. Department of Housing and Urban Development (HUD) of 800 µg/ft$^2$ for exterior concrete or other rough surfaces (HUD 1995), there are no enforceable standards for lead dust on exterior surfaces and none have been incorporated into the U.S. federal regulatory standards. There are also no federal regulations covering lead dust emissions from building or housing demolition. This research is intended to help inform better control of lead dust emissions from demolition of older housing likely to contain lead-based paint in order to reduce exposures to exterior lead contaminated settled dust.

**Methodology**

In Chicago, vacant housing units were selected for inclusion in the study through a unique collaboration between the local health, building and environment departments, the local gas company (gas shut-off is one of the final actions to occur prior to demolition and is reported to the department of environment), the University of Illinois at Chicago and the National Center for Healthy Housing. In Baltimore, the site was selected by the East Baltimore Development Initiative (EBDI) and was part of a major redevelopment effort in a specific location. In both sites, substantial community involvement was achieved through regular community meetings in Baltimore and through the Metropolitan Tenants Organization in Chicago.

In Baltimore, air, soil and exterior settled dust sampling was performed according to standard protocols developed by the National Institute for Occupational Safety and Health (NIOSH Method 7300), the Environmental Protection Agency (EPA Methods 3050, 6010, and 6020) and HUD (HUD 1995), respectively. In addition, lead dust fall was measured using a protocol developed by the American Public Health Association (APHA Method 502), as modified by Farfel et al. (see Figure 1). The Chicago site included lead dust fall measurements only (sampling of other particulate matter, including $PM_{10}$, $PM_2$, silica, asbestos and other metals will be reported in a future manuscript). In this paper, air monitoring refers to measurement of airborne lead particulate. On the other hand, lead dust fall sampling refers to measurement of lead particulate that settles out of the air. Lead dust fall was measured by the APHA method 502 as adapted by Farfel (Farfel et al. 2003). The method consisted of plastic containers with a defined surface area of 506.71 cm$^2$ filled with 1 liter of de-ionized water, elevated to breathing zone height and opened to the atmosphere for a measured period of time (see Figure 1). Sampling was either halted or not conducted when precipitation and/or high wind events occurred. Air monitoring and lead dust fall are two distinctly different sampling and analytical methods. The air sampling protocols were developed for use in occupational settings and had not previously been used to measure resident exposure in demolition activities.

**Figure 1. Lead Dust Fall Sampling Apparatus**


We sampled three types of sites in this study: demolition at multifamily housing in a specific geographic area in Baltimore; scattered single family housing in Chicago; and sites in both cities where no demolition was occurring (the latter are termed “background samples”). Demolition locations were defined as sites where housing demolition and/or demolition debris removal was actively occurring. In Chicago, background samples were collected to estimate ambient lead dustfall where no active demolition or debris removal was underway within a two block radius. In Baltimore, background samples were collected approximately 1 mile away from the demolition site and where there was no demolition within a 5 block radius. Blank samples were collected in both cities at regular intervals to determine if sampling media were contaminated.

To identify residential demolition sites in Chicago, we obtained prospective addresses through demolition permits. Direct visual observation determined if demolition was underway or imminent. This resulted in successfully finding a demolition site approximately 50% of the time in the pilot study, due to the extended length of the demolition permit (a month or more), the short length of time needed to demolish a single family home (1-3 days), and the lack of knowledge of the actual start date of demolition. To estimate more precisely the actual start date of demolition, we also obtained additional addresses scheduled for gas shut-offs from the utility company (gas shutoff is one of the final actions to occur prior to actual demolition. Using both sets of addresses, the success rate in identifying demolition increased to over 80%.

Once a demolition site was identified in Chicago, samplers were placed on public property at the building perimeter surrounding the location of interest. The distances from the sites to the samplers varied, but were approximately 5 - 10 meters away from demolition activity. Once the apparatus was secured, one liter of deionized water was poured into the container and the collection time was started. A nominal minimum of 4 samples were used for each sample location, one at each corner of the plot and another up to 20-30 meters downwind. Duplicate, side-by-side samples were collected at some locations to estimate method variability. Sampling was conducted as long as the demolition occurred for the day, generally six to eight hours per day. Sampling was concluded when the lid was attached to the sampling container and the time recorded. In Baltimore, samplers were located at fixed sites on streets within the demolition zone. Sampling was conducted over a nine month period and each sampling period was 6-8 hours. While some families remained near the demolition work in Baltimore, most of the area was vacated. However, in Chicago, nearby houses were not vacated and were typically three to five meters away from the demolition work site.

Following transport to the laboratory, deionized water from the sampler was first filtered through mesh to remove large extraneous material (if any), then through 0.8 micron glass filter paper, dried and digested and analyzed for lead by ICP/MS or AAS. All laboratory analysis was performed by a laboratory accredited by both EPA and the American Industrial Hygiene Association under the U.S. National Lead Laboratory Accreditation Program.

**Findings**

The results from Baltimore are shown in Table 1.

**Table1. Environmental Sampling Results from Baltimore multifamily housing with dust control**

| Media | Number of Samples | Geometric Mean | 95% Confidence Interval | US Federal Standard |
|---|---|---|---|---|
| | | | | |
| Airborne Lead During Demolition (µg/m$^3$) | 239 | <1.0 (all below detection limit) | Not Applicable | 1.5 (quarterly average) |
| Soil Lead Before Demolition (µg/g) | 16*** | 449 | 294, 686 | 400 (play areas) 1200 (yard) |
| Soil Lead After Demolition (µg/g) | 16*** | 166 | 102, 269 | 400 (play areas) 1200 (yard) |
| Exterior Settled (Wipe) Dust Lead Before Demolition (µg/ft$^2$) | 12*** | 74 | 24, 233 | 800** |
| Exterior Settled (Wipe) Dust Lead After Demolition (µg/ft$^2$) | 12*** | 44 | 21, 90 | 800** |
| Background Dustfall Lead (µg/m$^2$/hr) | 36 | <5.7 | Not Applicable | None |
| Dustfall (Lead) During Demolition (µg/m$^2$/hr) | 238 | <7.6$^A$ | 257* | None |
| Dustfall (Total Dust) During Demolition (µg/m$^2$/hr) | 238 | 6,840 | 58,300* | None |

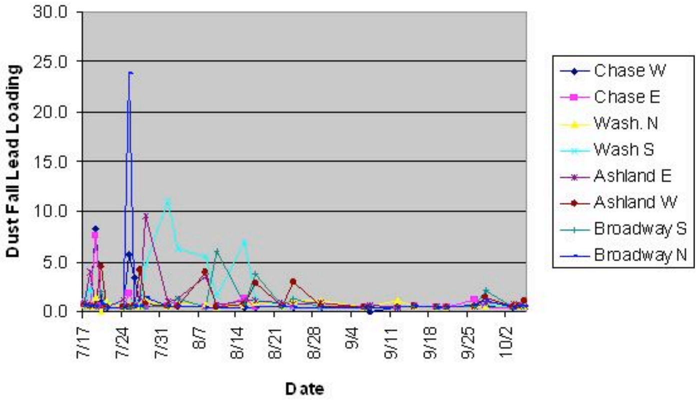
A = 66% of the observations were less than the detection limit (DL). For this estimate of the geometric mean, values below the detection limit (DL) were substituted with the DL and consequently the geometric mean reported in the table is higher than the actual geometric mean.
* Maximum
** HUD Guideline for exterior surfaces
*** Matched by location pre- and post- demolition soil samples (pilot study)

In Baltimore, the sample results for airborne lead (not lead dustfall) were all below detection limits (<1 microgram of lead per cubic meter of air), both before and during demolition. Exterior dust wipe samples varied to a high degree. Soil lead levels declined following demolition activities, possibly because some topsoil was removed during the debris removal stage. Exterior dust lead levels from wipe sampling also declined following demolition, possibly because of the street and sidewalk cleaning that occurred.

Given the fact that lead dust is dense and consists of mostly larger particles, it is not surprising that airborne dust lead levels were too low to be measured, because lead dust can be expected to settle from air relatively quickly. Occupational exposures to lead dust during housing demolition were not measured here, but may be expected to be considerably greater than the community levels measured here. There is uncertainty about the use of exterior dust wipe sampling to fully and properly characterize community exposures (wipe sampling on sidewalks has not been shown to be related to children's blood lead levels).

Levels of lead dustfall and total dustfall were both highly variable in both cities, although more than half of the results were below the detection limit. Figure 2 shows the variability of lead dust fall by location and time in Baltimore. The large increase on July 24 was due to the unexpected collapse of several buildings prior to demolition.

**Figure 2. Lead Dustfall in Baltimore From Multfamily Housing Demolition With Dust Suppression by Sampling Location Street and Date**




| *Site* | *# Days* | *Arithmetic mean* | *Minimum* | *Maximum* |
|---|---|---|---|---|
| Chase W | 29 | 1.997 | 0.000 | 10.600 |
| Broadway N | 30 | 2.458 | 0.003 | 20.400 |
| Chase E | 30 | 5.350 | 0.038 | 58.300 |
| Broadway S | 30 | 7.193 | 0.003 | 49.700 |
| Ashland W | 30 | 6.203 | 0.001 | 16.300 |
| Wash S | 30 | 6.801 | 0.019 | 30.000 |
| Wash. N | 29 | 6.821 | 0.001 | 41.800 |
| Ashland E | 30 | 17.737 | 0.008 | 55.800 |
| All Sites | 238 | 6.840 | 0.000 | 58.300 |

The dustfall sampling results from Chicago are shown in Table 2. Generally, they show that both total dustfall and lead dustfall are much higher for demolition than in Baltimore. The geometric mean lead dustfall in Chicago was 29.6 µg/m$^2$/hr, while in Baltimore it was less than 5.7 µg/m$^2$/hr, even though far more houses were demolished in a smaller geographic area over a shorter time period than in Chicago. The difference in the maximum lead dustfall in the two cities is even more striking. In Baltimore, the maximum lead dustfall was 257 µg/m$^2$/hr, but in Chicago, the maximum was 32,000 µg/m$^2$/hr. Total dustfall was also far higher in Chicago than in Baltimore.

**Table 2. Environmental Sampling Results from Chicago (67 single family housing units)**

| Media | Number of Samples | Minimum | Maximum | Geometric Mean | Geometric Std Dev |
|---|---|---|---|---|---|
| Lead in Dustfall (%) | 436 | <0.001 | 0.16 | 0.0018 | 7.3 |
| Background Dustfall Lead (µg/m$^2$/hr) | 43 | <0.35 | 20 | 1.8 | 3.1 |
| Dustfall (Lead During Demolition (µg/m$^2$/hr) | 442 | 1.4 | 32,000 | 29.6 | 8.3 |
| Dustfall (Total Dust During Demolition) (µg/m$^2$/hr) | 442 | 227 | 19,100,000 | 15,200 | 10.7 |

The observed dust suppression techniques, demolition protocol and community involvement in Baltimore consisted of the following: 1. Substantial use of water throughout the process to reduce the spread of dust, including 2 to 4 fire hoses, which were used prior to building razing both at the top of the building and at the bottom, as well as continuously during the building razing and debris removal stage. During building razing, the building was kept wet with at least one fire hose, while at least one other fire hose was used to apply water to the debris removed by the "picker" or other equipment. This amount of water use was believed to be substantially more than traditional demolition, which sometimes does not include dust suppression through wet methods, or may only consist of a single hose used intermittently. 2. Training for community residents about the enhanced demolition protocol; 3. Training for community residents about safety measures at home; 4. Provision of community residents with cleaning supplies (e.g. HEPA vacuums) to reduce any dust lead exposure in individual homes; 5. Training of community block monitors to observe the demolition process and to assist residents with questions and home safety measures; 6.

Required training in lead safe work procedures for salvage, deconstruction, and demolition crews; 7. Facilitating better communication among city agencies including Baltimore Housing, Public Works, Transportation, Police, and a public telephone call center; 8. Widespread notification to residents, community organizations, faith-based organizations, and city agencies about when and where demolition would be happening; 9. Posting of highly visible signage on the houses to be demolished; 10. Careful demolition using the "picker method" (instead of the more traditional wrecking ball, bulldozing or implosion methods), together with high fencing and jersey barriers to control debris and dust and unauthorized entry, and sediment control; 11. Third party monitoring for air, dust fall, dust wipe and soil testing throughout the process; 12. Removal and safe disposal of some architectural components with high lead content prior to demolition (deconstruction) when the building was structurally sound; 13. Architectural salvaging and preservation of historically significant items when the building was structurally sound; 14. Visible signage on blocks after demolition indicating the future use of the block; 15. Greening and ongoing maintenance of blocks after demolition to control re-entrainment of dust from bare soil; 16. Street and sidewalk cleaning after demolition and debris removal; and 17. Designation of a full time dust suppression manager.

Figure 3 depicts demolition in Chicago (where dust suppression was not continuous) and Baltimore (where the EBDI demolition dust suppression protocol was used).

**Figure 3. Demolition in Baltimore (dust suppression) and Chicago (little dust suppression)**


Above left: Dust suppression in Baltimore (2 hoses) plus jersey barriers and poly covered fencing
Above right: Little dust suppression in Chicago (note proximity of observer), no barriers, no fencing

**Discussion**

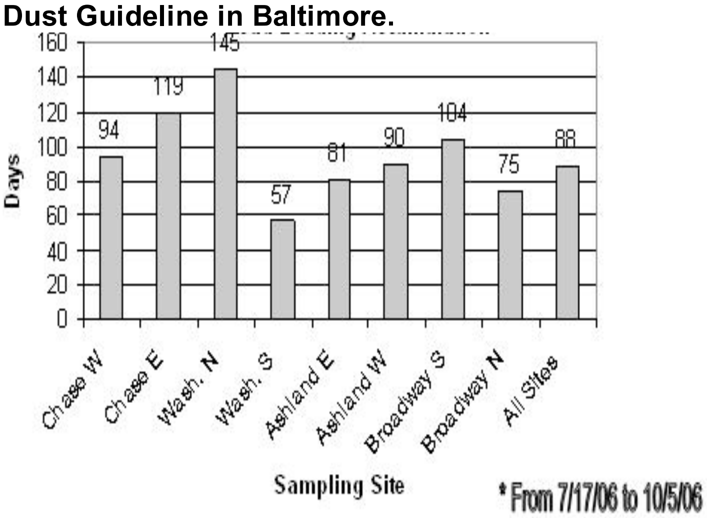
This study demonstrates that control of lead dust from housing demolition is feasible and necessary. It also demonstrates that sampling of lead airborne lead dust is less informative than is measurement of lead dustfall, because airborne dust lead results are more likely to be below the limit of detection.

Previous studies of demolition were from large multifamily housing sites or multiple row homes, where people did not live close to demolition activities (Farfel et al. 2003; Dorevitch et al. 2006). Table 3 compares the results from the recent studies in Chicago and Baltimore with an earlier 1999 study of multifamily housing demolition (also in Baltimore). The 1999 study used less dust suppression than the 2006 Baltimore study and also had a smaller number of demolished houses. The results show that dustfall lead emissions from multifamily housing demolition can be much larger than single family housing demolition, probably because more surfaces are disturbed. At the same time, single family housing demolition is more likely to be conducted in neighborhoods where most residents are still present and where exposures to community members may be greater. Our data in Chicago may indicate higher cumulative exposures due to more frequent exposure and closer proximity to single-family home demolition. Houses in Chicago also tend to be only 3 to 5 meters apart from each other, with neighboring properties remaining occupied while demolition occurs nearby. Demolition therefore almost always has the potential for release of lead in dustfall within close proximity to occupied homes and apartments where the population at greatest risk (children), are likely to reside. A recent study found that exposure to demolition activity is related to elevated blood lead levels in children (Rabito et al. 2007).

**Table 3. Comparison of Lead Dust Fall Results**

| Study | Geometric Mean Lead Dustfall (Background) (µg/m$^2$/hr) | Geometric Mean Lead Dustfall (Demolition) (µg/m$^2$/hr) | Maximum Lead Dustfall (Demolition) (µg/m$^2$/hr) |
|---|---|---|---|
| Baltimore (2006) Multifamily Housing Demolition Using Dust Suppression (900 units) | <5.7 | <7.6 | 257 |
| Chicago (2007) (Single Family Housing, Little or No Dust Suppression) (67 units) | <1.8 | 29.6 | 32,000 |
| Baltimore (1999) Multifamily Housing Demolition, Limited Dust Suppression, approx 150 units) | 10 | 410 | 6,400 |

**Figure 4. Estimated Duration of Demolition Activity Needed to Exceed the HUD Exterior Dust Guideline in Baltimore.**




The HUD exterior surface cleanup guideline can be converted into µg/m$^2$/hr if we assume a one hour time frame, yielding 8,600 µgPb/m$^2$/hr. Using the Baltimore data, it is possible to calculate how many days of continuous demolition activity would be needed before settled dust lead levels exceed the current HUD exterior dust guideline of 800 µg/ft$^2$ at each sampling site (Fig 4), assuming that no lead dust is re-entrained or washed or blown away (because such losses are likely, this is a conservative health protective assumption). For example, at the Chase W sampling location, it would take 94 days of full time eight hour a day demolition to exceed 800 µg/ft$^2$. Using the maximum lead dustfall rate of 257 µg/m$^2$/hr from the Baltimore 2006 data, it would take 33 hours of continuous demolition activity to exceed the guideline, assuming no loss to wind, rain, or re-suspension. But using the maximum lead dustfall level seen in Chicago where dust suppression was much less (32,000 µg/m$^2$/hr), the HUD guideline would be exceeded in only 16 minutes of demolition activity. This suggests that much more extensive controls and regulation of housing demolition, especially single family housing demolition, is needed to prevent significant exposures to neighbors and the community. Such controls are fairly straightforward and feasible.

**Summary**

Large amounts of lead-contaminated dust are generated from housing demolition, but can be controlled using simple dust suppression to protect the public health.

**References**

Adebamowo EB, et al. 2007. Lead content of dried films of domestic paint currently sold in Nigeria. Science of the Total Environ. Article in Press. Available on line at www.sciencedirect.com

Brody DJ, Brown MJ, Jones RL, Jacobs DE, Doa MJ, Ashley PJ, et al. 2005. Blood lead levels—United States, 1999-2002. MMWR 54: 513-516.

Clark CS, et al. 2006. The lead content of currently available residential paint in several Asian countries. Environ Res 102: 9-12

Dorevitch, S., H. Demirtas, et al. (2006). "Demolition of high-rise public housing increases particulate matter air pollution in communities of high-risk asthmatics." J Air Waste Manag Assoc 56(7): 1022-32.

EPA 2001. Lead; Identification of Dangerous Levels of Lead. Final Rule. 24 CFR Part 745. Jan 5, 2001. Federal Register 66 (4) 1206.

Farfel MR, Anna O. Orlova, Peter S.J. Lees, Charles Rohde, Peter J. Ashley, and J. Julian Chisolm, Jr. A Study of Urban Housing Demolitions as Sources of Lead in Ambient Dust: Demolition Practices and Exterior Dust Fall Environ Health Perspect 111:1228-1234 (2003)

Farfel MR, Orlova AO, Lees PS, Rohde C, Ashley PJ, Julian Chisolm J Jr. A study of urban housing demolition as a source of lead in ambient dust on sidewalks, streets, and alleys. 2005. Environ Res Oct;99(2):204-13.

HUD 1995. Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing, Department of Housing and Urban Development, Washington DC. Available at: http://www.hud.gov/offices/lead/lbp/hudguidelines/index.cfm

Jacobs, David E. 1995. Lead Paint as a Major Source of Childhood Lead Poisoning: A Review of the Evidence, in: Lead in Paint, Soil and Dust: ASTM STP 1226, Philadelphia, PA

Jacobs DE and Nevin R. Validation of a Twenty-Year Forecast of U.S. Childhood Lead Poisoning: Updated Prospects for 2010, Environ Res 102(3) 352-364, Nov 2006.

NCHH 2004. Evaluation of the HUD Lead-Based Paint Hazard Control Grant Program, Final Report, available at: http://www.nchh.org/HUD_National__Evaluation_Final_Report.pdf

Rabito, F. A., S. Iqbal, et al. (2007). "The association between demolition activity and children's blood lead levels." Environ Res 103(3): 345-51.

WHO 2003 Lead: Assessing the environmental burden of disease at national and local levels. WHO Environmental Burden of Disease, Series 2. Geneva. 2003

WHO 2006. Report on the WHO Technical Meeting on Quantifying Disease from Inadequate Housing. Bonn, Germany Nov 2005. pages 90-97

Vojta, P. J., W. Friedman, et al. (2002). "First National Survey of Lead and Allergens in Housing: survey design and methods for the allergen and endotoxin components." Environ Health Perspect 110(5): 527-32.