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An exterior and interior leaded dust deposition survey in New York City: Results of a 2-year study

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Abstract

Environmental concentrations of leaded dust were monitored by weekly sample collection of interior and exterior settled dust that had accumulated due to atmospheric deposition. The weekly deposition amounts were measured and the cumulative rates of lead in dust that deposited on a weekly basis over 2 year's time were determined. The sampling analysis revealed that the median values of leaded dust for the interior plate (adjacent to the open window), unsheltered exterior plate, and the sheltered exterior plate were 4.8, 14.2, and 32.3 µg/feet^2/week, respectively. The data supports the existence of a continuous source of deposited leaded dust in interior and exterior locations within New York City. Additional data from a control plate (interior plate with the window closed) demonstrate that the source of the interior lead deposition was from exterior (environmental) sources. Because of the ubiquitous nature of lead in our environment and the toxic threat of lead to the cognitive health of children, this data provides a framework for the understanding of environmental exposure to lead and its potential for continuing accumulation within an urban environment.

Keywords: Lead; Dust; Indoor; Outdoor; Lead poisoning; Sources; Air; Exposure; Ambient; Background; Atmospheric deposition; Lead loading; Urban

1. Introduction

Mild to moderately elevated blood lead (EBL) levels in children are a major public health concern (Agency for Toxic Substances and Disease Registry, 1988). Recent studies have demonstrated toxicological effects including a decrease in cognitive function at blood lead levels previously thought to be safe (Canfield et al., 2003; Needleman, 2004). Significant environmental source reductions have been implemented over the past three decades (Agency for Toxic Substances and Disease Registry, 1988; Breen and Stroup, 1995). This has aided in lowering the number of children with elevated lead levels (CDC, 2000, 2005; Meyer et al., 2003). The number of children reported with confirmed EBL levels greater than 10 µg/dL has steadily decreased from 130,512 in 1997 to 74,887 in 2001 (Meyer et al., 2003).

Settled as well as airborne lead contaminated dust within the household and the environment represents a dynamic and continuous source of exposure (Lanphear et al., 1998a). Lead dust is present on almost any object that a child might contact or mouth. Thus, a continuously varying diet of lead would not be unreasonable to assume in children with even minor hand-to-mouth activity (Arbiter and Black, 1991; Duggan and Inskip, 1985; Lanphear et al., 1998b; Lin-Fu, 1973). Such activity need not rise to the level of pica. Based on the data presented in this investigation, we offer the observation that one source of lead exposure in children may arise from interior dust contaminated with external atmospheric deposition of leaded dust and need not be solely from flaking or peeling lead-based paint chips.

The sources of environmental lead are multifaceted and often dependent on past industry (Farfel et al., 2003;

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Table 1
Sampling locations and influencing parameters

Sampling plate	Influencing parameter				
	Number of weeks sampled	Direct atmospheric deposition (fallout)	Precipitation (dew, rain, snow)	Wind	Wafting
#1—interior	104	No	No	No	Yes
#2—exterior unsheltered	104	Yes	Yes	Yes	No
#3—exterior sheltered	36	Yes	No	Yes	No
#4—control	7	No	No	No	No

Lanphear et al., 1998a; Roychowdhury, 1998). Given the ubiquitous nature of environmental lead, identification of its origin is difficult. However, lead-based paint within a residence is often the prime suspect as the source(s) when a child in that residence presents with an EBL (Centers for Disease Control, 1991).

The prevalence of lead-based paint hazards increases with the age of housing, but many painted surfaces do not have lead-based paint (Jacobs et al., 2002). It has been reported that between 2% and 25% of painted building components were coated with lead-based paint (Jacobs et al., 2002). Thus, in excess of 75% of the etiology of lead is unaccounted for. Therein lies the difficulty, namely, to assign an attributable risk to any one lead source and then, to estimate the extent of contribution of each potential source(s) of lead to an EBL in children, whether they are urban or rural. The published scientific literature does contain studies that support exterior lead sources (those that are outside of a residence) as contributing sources of interior lead (Bushnell and Jaeger, 1986; Farfel et al., 2003; Lanphear et al., 1998b; Roberts et al., 1999; Wong et al., 2000).

This paper demonstrates that settled leaded dust, from ambient, exterior sources, is a continuous and varying source of lead exposure to all individuals, but especially to children who reside in urban areas. We present 2 years of both interior and exterior sampling data of settled dust deposition. The purpose of this research is two-fold: first, our goal is to understand the distribution of quantities of settled lead dust on exterior and interior surfaces in New York City; and second, we expect to establish background levels of lead dust loading on interior and exterior surfaces.

2. Materials and methods

Historically, the quantification of atmospheric dust fallout involved either of two collection methods; open face "bucket" or "inverted Frisbee" devices. Both these methods involve 1-month sampling periods with relatively small surface areas. However, due to the small surface areas involved and our desire to determine weekly fallout quantities these collection methods proved inadequate. In short, the weekly lead dust values from small collectors risked being below analytical detection limits. In addition, the above methods collected wet deposition (rain would collect in the "buckets") and we sought to explore the steady state surface dust loading of weather-exposed surfaces and other interior and exterior surfaces.

2.1. Thick glass plate collectors

Dust wipe samples were collected each week from horizontal one-quarter inch thick glass plates measuring 3 × 3 feet^2 (total area of 9 feet^2). This large sampling surface was judged necessary to ensure adequate collection of material for analytical detection. All of the glass plates were placed on 30-in high, plastic sawhorses that were located on the southeast side of a second story rooftop of the Health Sciences Building at Hunter College. The facility is located at the intersection of First Avenue and 25th Street in Manhattan, New York.[1] To ensure the glass plates were not a source of lead, a small section of the glass plate was tested for lead leachability as per American Society for Testing and Materials (ASTM) Method C738 (ASTM International, 1999); there was no detectable leachable lead. At our sampling location in New York City, there was little, if any, immediate source of paint (leaded or not), as the outside of these buildings was brick. A total of four sampling plates were installed at the test facility. Table 1 describes the influencing parameters for each sampling location including direct atmospheric deposition, precipitation, wind and wafting.

2.2. Interior glass plate (adjacent to open window)

One glass plate was placed indoors in an unused emergency rooftop stairwell (see Fig. 1); it was adjacent (within 25 feet) of the exterior location of an identical (outdoor) glass plate; both were sampled for 104 weeks. The stairwell, constructed of masonry (ceramic coated cinder block) and free of lead-based paint[2] contained two windows (south and north). The steam heating unit (a metal radiator) was painted and the paint was uniform, intact and lead-free, per results of X-ray fluorescence (XRF) testing. The ventilation unit was not a forced hot air system, but was a convection unit and provided no positive or negative pressure gradient. In an effort to stimulate interior/exterior air exchange typical of residential living, an adjacent window (south side) was opened slightly (1"). Air movement from the outside to the inside of the room was confirmed using smoke tubes.

2.3. Unsheltered exterior glass plate

The exterior sampling site was located on the northeast corner of the roof (see Fig. 2), and completely open to the ambient environment (i.e. susceptible to the influence of rain, snow, wind). This plate is referred to as the unsheltered outdoor sample. As noted, leaded dust was collected from this plate on a weekly basis for 104 weeks (2 years).

[1]This location is approximately midtown of the 14-mile long Manhattan island close to the east side, two blocks from the East River. The area is a mixture of downtown offices and residential apartment buildings with large medical facilities. It is strictly a high-density urban area with high vehicular traffic.

[2]Inspected by J. Caravanos, NJ licensed lead inspector. A NITON XL 309 XRF lead detection device was used.

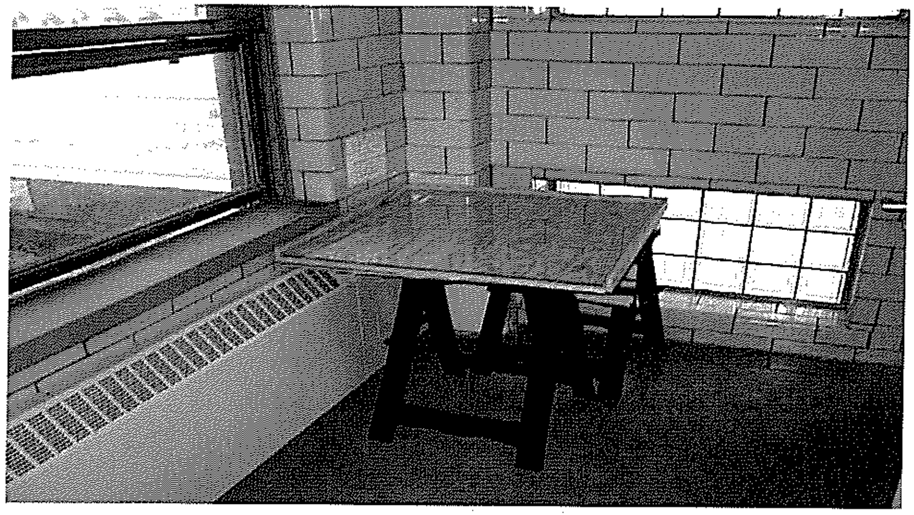

Fig. 1. Interior sample location viewed from the east side room entry.

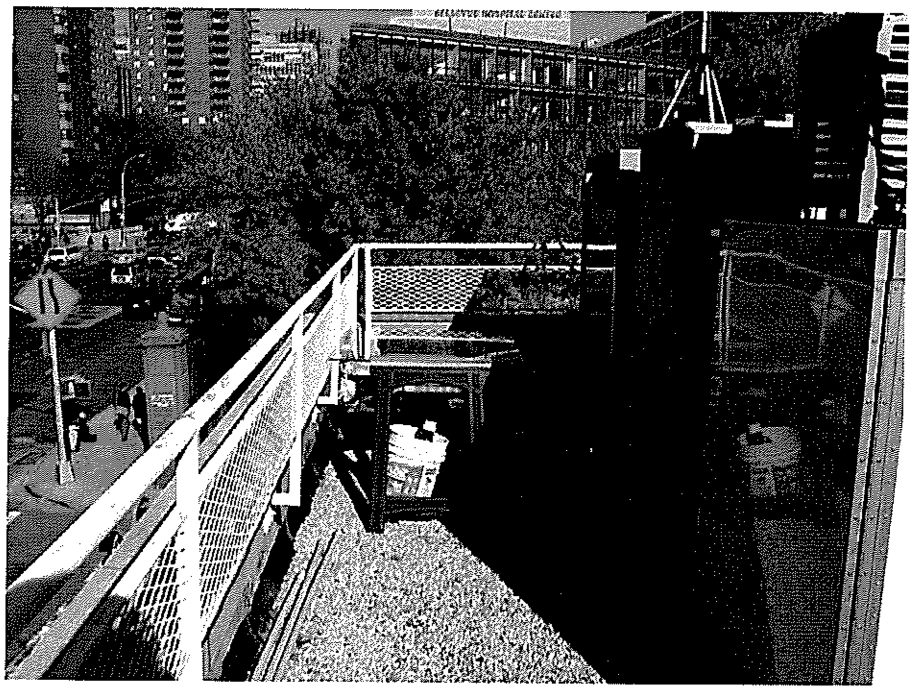

Fig. 2. Exterior unsheltered sample plate viewed from the south.

2.4. Sheltered exterior glass plate

A third glass plate was placed outside the stairwell; however, this outdoor plate was shielded by a portico and therefore the sample site did not receive rainfall or experience atmospheric washout as did the second (outdoor and uncovered) glass plate. The purpose of the second outdoor plate was to examine the effect of precipitation. Sampling of this plate was only performed during the final 36 weeks of the study. This plate will be referred to as "sheltered."

2.5. Interior control glass plate (adjacent to closed window)

Lastly, a fourth glass plate was installed in another nearby (also unused) emergency rooftop stairwell; this served as an interior control site. In this stairwell, the windows were kept closed and none to very little air exchange with the exterior occurred. This stairwell was identical to the other interior site including the ventilation unit. Sampling of this location was performed concurrently with the other sample sites. A sampling time of 7 weeks was used. Sampling was abandoned due to resource limitations and a continuing negative result.

Dust deposited on each glass plate was collected once per week by careful wiping. At 1-week time intervals, the technician, using clean, single use, disposable latex gloves, wiped the surface. The established protocol consisted of thoroughly wiping the glass plate until all visible mass was removed, then using one additional (final) wipe to ensure complete collection. Quality control testing confirmed this protocol collected all deposited material at 'reasonable' dust loading. Thus, a minimum of 2 wipes was used. However, on occasion, four wipes were necessary due to the magnitude of dust deposition (especially for the sheltered plate). Standard Housing and Urban Development (HUD) lead dust wiping techniques (Appendix 13.1 HUD Guidelines) (Jacobs, 1995) were employed. The wipes (Pallintest, Erlanger, KY) complied with the ASTM E 1792 guideline.

All samples were packaged in plastic 50 mL centrifuge tubes and were sent to an American Industrial Hygiene Association/Environmental Lead Laboratory Accreditation Program (AIHA/ELLAP) accredited commercial laboratory.[3] Samples were prepared following HUD Appendix 14.2 Guidelines (Jacobs, 1995). Flame atomic absorption spectrophotometry (EPA Method 7420)(EPA, 1986) was used to quantify lead in the dust samples. Weekly sampling occurred every Monday (noon) and began in March 2003 and continued to March 2005. This document reports on the 104 weeks for the exterior and interior lead samples; the exterior sheltered plate was sampled for the last 36 weeks of the project while the control was sampled for 7 weeks.

3. Results

Table 2 shows the mean and median lead dust loading as well as the minimum and maximum values for the four glass plates. At the time of weekly sampling, three of the four glass plates tested disclosed measurable amounts of leaded dust. The interior control plate did not have any lead as surficial dust. This fourth glass plate, acting as the interior control, was located in an interior stairwell with closed windows; there was little to no traffic and this location revealed no lead accumulation (sampling abandoned after 7 weeks of negative lead dust loadings). As this served as the control for the other interior plate) adjacent to the open window, the result demonstrates that the source of the interior leaded dust was from air being carried or wafted through the open window. Based on this, the source of lead on the interior glass plate adjacent to the open window was from dust carried through the window opening. We conclude this since the stairwell was not otherwise used; it contained no source of leaded dust.

With respect to the lead deposition, three of the four glass plates showed the weekly presence of lead. The sample analysis revealed that the minimum and maximum values for leaded dust for the interior plate (adjacent to the open window) were 1.6 μg/feet^2/week and 40.8 μg/feet^2/week, respectively, with a corresponding median value of 4.8 μg/feet^2/week. Similarly, the minimum and maximum values for leaded dust for the exterior unsheltered plate were 1.6 and 62.0 μg/feet^2/week, respectively, with a corresponding median value of 14.2 μg/feet^2/week. The third glass plate, placed outdoors but sheltered from the rain and snow by a portico, also revealed increasing lead amounts at greater concentrations than the unsheltered plate. The minimum and maximum values for leaded dust on the sheltered exterior plate were 10.6 and 53.5 μg/feet^2/week, respectively, with a corresponding median value of 32.3 μg/feet^2/week. A comparison between both exterior plates demonstrates the effect of precipitation prior to sampling. Since the plates were sampled every Monday, the precipitation and wind patterns during the previous week clearly impacted the deposition and accumulation of leaded dust.

Fig. 3 demonstrates the cumulative lead deposition in μg/feet^2 over the sampled periods. The shape of the graph supports the dynamic and continual deposition of leaded dust in this urban environment. The US Environmental Protection Agency (EPA) Standard for interior floor dust lead hazard level is currently 40 μg/feet^2. The data show that, based on mean values, this amount is likely to be exceeded in five or six weeks time. Depending on the rate of deposition and location, within any given week, the standard for the lead content in floor dust may be exceeded in less time.

As noted, the sheltered plate, the unsheltered plate, as well as the interior plate adjacent to the open window all accumulated lead. Both exterior surfaces accumulated lead more rapidly with a steeper accumulation curve than did the interior glass plate (see Fig. 4). The 36-week sampling of the sheltered glass plate reveals a greater rate of lead accumulation than the unsheltered plate, most likely due to the lack of an effect of precipitation (wash-off) that occurred on the unsheltered plate. In this regard, the mean slopes measured were as follows:

- Pb loading exterior (unsheltered)17.5 μg/feet^2/week,
- Pb loading exterior (sheltered)33.1 μg/feet^2/week,
- Pb loading interior7.4 μg/feet^2/week.

These slopes were remained relatively constant for both year one and two. The lead accumulation rate for the sheltered exterior plate was generally double the exterior

Table 2
Atmospheric lead deposition in μg/sf/week at locations that accumulated lead during March 4, 2003–March 3, 2005

	Pb (μg/sf/week) interior	Pb (μg/sf/week) unsheltered	Pb (μg/sf/week) sheltered[a]
Year 1			
Mean	8.4	17.1	—
Median	4.9	13.1	—
Ninetieth percentile	20.6	31.2	—
Minimum	1.6	1.6	—
Maximum	40.8	62.0	—
Year 2			
Mean	6.4	17.9	33.1
Ninetieth percentile	11.9	34.5	49.0
Minimum	1.6	1.6	10.6
Maximum	25.1	48.3	53.5
Combined[b]			
Mean	7.4	17.5	33.1
Median	4.8	14.2	32.3
Ninetieth percentile	15.8	33.9	49.0
Minimum	1.6	1.6	10.6
Maximum	40.8	62.0	53.5
Std. deviation	7.0	12.6	11.4

Note: The interior control plate was negative (i.e. < 1.6 μg/sf/week) as sampled.

[a]Only 36 weeks of sampling was done at this location.

[b]There no statistical difference between years 1 and 2 sampling mean values.

[3]Lab analyses by Schneider Laboratories Inc. (Richmond, VA)

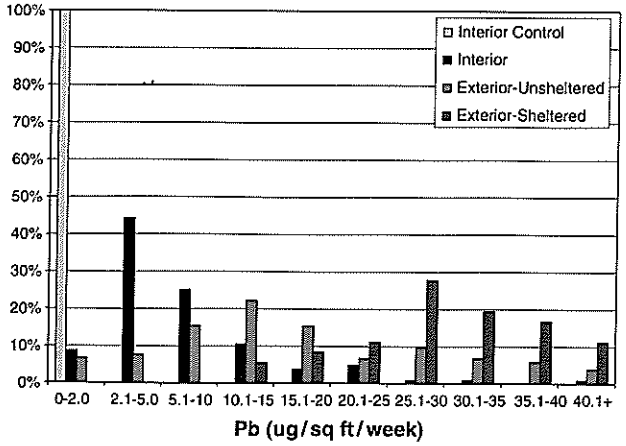

Fig. 3. Distribution of the cumulative lead deposition in μg/feet²/week over the sampled periods for the four sampling locations. (*Note*: 100% of the interior control values were below detectable limits).

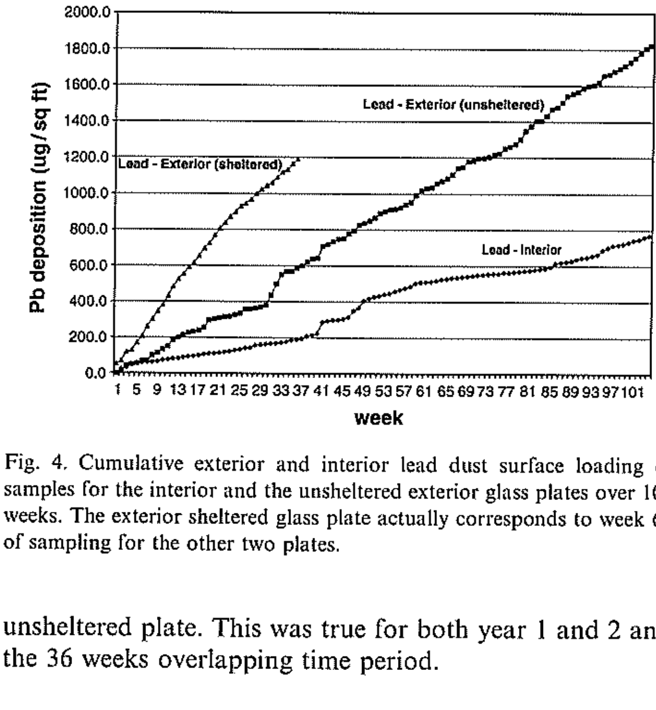

Fig. 4. Cumulative exterior and interior lead dust surface loading of samples for the interior and the unsheltered exterior glass plates over 104 weeks. The exterior sheltered glass plate actually corresponds to week 68 of sampling for the other two plates.

unsheltered plate. This was true for both year 1 and 2 and the 36 weeks overlapping time period.

4. Discussion

This study demonstrates the ubiquitous nature of lead in the urban atmospheric environment. We do not know the exact sources of the exterior leaded dust. However, several likely sources are present in the urban environment (Agency for Toxic Substances and Disease Registry, 1988; Mielke, 1993). Additional data on the deposition of lead in the five boroughs that comprise New York City is in press.[4] With respect to lead, road grit contains lead from many sources including atmospheric fallout from past use of leaded gasoline, lead weights used to balance tires and industrial uses of lead in electronics and automotive parts as well as leaded paint. Exterior paint on the road (yellow lines) and a variety of street fixtures often contain leaded paint on their surface. Lead chromate is a widely used pigment on exterior signage. Furthermore, building renovation and demolition as well as bridge repair may release dust from lead-based paint. This occurs despite "best" efforts to control the release of leaded dust. Soil contamination is especially common alongside streets and near high-traffic areas (Agency for Toxic Substances and Disease Registry, 1988). Although lead is no longer used as an additive in gasoline, lead weights are currently used to balance tires. These weights are lost and deposited along urban streets; they accumulate along the curb(s) and are rapidly abraded and ground into tiny pieces by vehicle traffic. Lead from this source (wheel weights) is continuous, significant, and widespread. These lead particles, dusts, and scrapings may be deposited in the soil in heavily trafficked areas (Root, 2000).

The data presented in this study demonstrates that interior dust contaminated with lead most likely results from dust being wafted and blown inside a residence/building. The only source of the lead on the interior glass plate was derived from exterior sources. The results of our study are consistent with other studies in the published literature (Aschengrau et al., 1997; Bornschein et al., 1986; Clark et al., 2004; Laidlaw et al., 2005). Clark et al. (2004) demonstrated through statistical modeling a pathway from exterior entry dust lead loading to loadings on interior entryway floors, other interior floors, and windowsills. Hunter (1977) demonstrated that children's lead levels are higher in the summer months than during the winter months when they are more often indoors. This is consistent with more dust in the house because of open windows and the frequency of passage inside and outside. Recent data by Laidlaw et al. (2005) has demonstrated that when the temperature is high and evapotranspiration maximized, soil moisture decreases and soil dust is mobilized.

In another study, investigators assessed the relationship between lead-based paint and associated surficial dust by using isotopic ratio analysis (Jaeger et al., 1998). They reported that paint samples from one house did not match the associated surficial dust in the house in four out of the five samples taken. They observed that when the paint was intact, the lead in the dust did not match isotopically to the lead in the paint on the test surface. Isotopic ratio measurements can be useful for a 'fingerprinting' of the source by virtue of sample match and by placement of the ratio on the spectrum of isotopic ratio values for lead (Angle et al., 1995; Manton, 1977; Rabinowitz, 1987; Rabinowitz, 1995).

Atmospheric deposition of lead is dynamic and continual as evidenced by the data obtained in this study over a 2-year period. It is startling to find that the interior lead dust standards may be exceeded after only 3 weeks of

[4]Caravanos, J., A.L. Weiss, M.J. Blaise, R.J. Jaeger. 2005 A survey of spatially distributed dust lead loadings in New York City. Environmental Research, in press.

accumulation. This suggests that in some households, hygiene practices may be critical to the mitigation of lead exposure to young children. Hygiene practices would include increased cleanliness within the residence and frequent wiping of floors and windowsills for accumulated dust. The extent and length of the window openings may affect the interior lead dust accumulation. However, this study was not designed a priori to address this variable and is worth consideration in a future study. Interior lead dust accumulation will also be influenced by atmospheric deposition rate, precipitation, and wind speed and direction. In addition, interior dust management (frequent wiping and mopping) should be routine hygienic practices, especially in urban and high traffic areas. The outdoor accumulation of lead dust appears to remain a major issue and that a new method must be found to remedy the accumulated lead dust in the city to reduce exposure to urban children.

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