THE EFFECTIVENESS OF A HOME CLEANING INTERVENTION STRATEGY IN REDUCING POTENTIAL DUST AND LEAD EXPOSURES[4]

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The changes in dust loading, lead loading and lead concentration, determined from vacuum samples and wipe samples collected during the Childhood Lead Exposure Assessment and Reduction Study (CLEARS) were analyzed to determine the efficacy of the cleaning protocol in homes of children found to have moderate lead poisoning, e.g. levels between 10–20 μg/dL. The samples were collected at least twice, and in 65 homes three times, during the course of a year long intervention in homes where half were randomized into a group which received a standardized Lead Intervention program for lead reduction, and the other homes only received an Accident Intervention program. The homes with lead burdened children were located in Hudson County, New Jersey (primarily in Jersey City), and were referred to the CLEARS by a number of private and public sources. Each home had wipe sampling conducted with the LWW Sampler (patented), and vacuum sampling was completed using a device described by Wang et al. in Applied Occupational and Environmental Hygiene. *The results were compared in two ways: (1) between the two intervention groups, and (2) over the time course of the intervention period. When compared to the values seen in the first visit vacuum sampling results showed statistically significant decreases in lead loading and dust loading by the third sampling visit for the Lead Intervention homes. Substantial reductions in lead loading and dust loading were also seen when the Lead Intervention values were compared to values obtained in the Accident Intervention homes over the course of the year long intervention. The wipe sampling results for the 65 homes with three visits found no significant reductions in dust loading and lead loading among any of the room surfaces sampled in the Accident Intervention homes. There were 75% and 50% reductions observed on the window sills and on the bedroom floors of the homes which*

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2. Abbreviations: ANOVA, Analysis of Variance; CLEARS, Childhood Lead Exposure Assessment and Reduction Study; CV, coefficient of variation; EOHSI, Environmental and Occupational Health Sciences Institute; FAA, flame atomic absorption; GFAA, graphite furnace atomic absorption; HEPA, high efficiency particle air; ICP-MS, inductively coupled plasma-mass spectrometer; NIST, National Institute of Standards and Technology; USEPA, U.S. Environmental Protection Agency.

3. Key words: house dust, lead exposure, lead intervention, vacuum samples, wipe samples.

4. Note: Part of the Childhood Lead Exposure Assessment and Reduction Study (CLEARS).

Journal of Exposure Analysis and Environmental Epidemiology, Vol. 8, No. 1, pp. 17–35

ISSN: 1053-4245

participated in the Lead Intervention. The levels in the living room and the kitchen showed very little change in loadings. This appeared to be due to the fact these rooms were near a background or baseline value of 0.3 g/cm² and 0.12 mg/cm² for dust loading and lead, respectively. This was substantiated by the window sills and bedroom wipe sampling results since each surface approached these values by the third visit. Significant reductions in lead concentrations found in the wipe samples from the intervention homes appeared to be related to the absence of historically active sources of lead in these homes, rather than elimination of current sources. The results of the micro-environmental sampling program in CLEARS indicated that a year long cleaning protocol can significantly decrease lead levels in rugs and on other exposed surfaces. This will reduce the potential for exposure to lead among the occupants, especially children, that come in contact with such surfaces.

INTRODUCTION

The quantity of dust deposited on rugs and various flat surfaces, such as table tops and window sills, as a metric of potential exposure to specific environmental contaminants, e.g., lead, and pesticides, has increased over the past ten years. The data gathered has improved our understanding of the nature of dermal and ingestion related exposures within residential settings (Vostal et al., 1974; Que Hee et al., 1985; Farfel et al., 1994; Farfel et al., 1994b; Millson et al., 1994; Lanphear, et al., 1995). The research reported here extends the use of deposited dust to evaluating the efficacy of a house cleaning protocol in reducing exposure to lead. The techniques were an integral part of the Childhood Lead Exposure Assessment and Reduction Study (CLEARS), which was conducted in the urbanized area, Hudson County, New Jersey (Rhoads and Lioy, 1992). The CLEARS was a systematic attempt to determine if a vigorous cleaning program could be employed to reduce blood lead in children known to be at risk to lead exposures. The study was designed as a randomized trial in which eligible participants were placed in a group that either received home cleaning and lead education for the mother, or accident prevention education to provide an intervention group and a control group, respectively. The effectiveness of the program in reducing blood lead levels is described in a paper by Rhoads et al. (1997).

The exposure measurement component of the CLEARS was conducted after an initial evaluation of the potential lead exposure pathways available to the subjects. It appeared that the lead levels in house dust would be the best indicators of exposure since no major active sources of airborne lead were present in the area, and the lead levels in the drinking water were low. To verify these assumptions active air samples and water samples were collected and analyzed periodically during the study. The geometric mean lead concentration in the indoor air was 32 ng/m³ with a range of < 3.0 to 547 ng/m³. The lead in tap water had a geometric mean of 3.4 ppb with a range of 0.40– 445 ppb (Rhoads et al., 1997). Further, information on proximate sources of lead found in the house dust were obtained by sampling paint, and soil and street dust. Subsequently, this information was used in a source apportionment of the house dust that established deposited airborne particles, chipped and flaked paint, and soil/street dust as the major contributors to house dust (Adgate, 1996).

With the selection of house dust as the major indicator of potential exposure, CLEARS built upon previous work that showed a relationship between household dust and toxic chemical exposure (Sayre and Katzel, 1979; Boonschein et al., 1985; Roberts et al., 1991; Lioy et al., 1992; Ewers et al., 1994; Roberts et al., 1995). In particular the chromium study done in Jersey City using the sampling techniques developed at the Environmental and Occupational Health Sciences Institute (EOHSI), and used in CLEARS, appeared to show that changes in house dust loadings were the best indicators of chromium reduction after remediation of hazardous wastes laden soil around a home or neighborhood (Lioy et al., 1992). In CLEARS, the house dust data were used to determine if vigorous cleaning of a home could achieve a reduction in the potential for contact with lead. Subsequently, the data would be used to determine if any changes in children's blood lead levels were significant when compared to the values for children living in the homes that only received accident prevention education. Thus, the dust sampling and analysis techniques were employed to establish trends in lead levels and potential exposure during the CLEARS cleaning intervention. The information reported here evaluates the efficacy of the cleaning protocols in reducing lead laden house dust in homes with children having low level lead poisoning, i.e., blood lead of between 10–20 µg/dL.

STUDY POPULATION

Children enrolled in CLEARS ranged in age from six months to three years old. They were recruited from neighborhood clinics, the Jersey City Childhood Lead Poisoning Prevention Program, and by referral from private physicians and other community sources (Rhoads et al., 1997). Subjects were eligible for participation if they met at least one of the following criteria: (1) reported blood lead value between 8 and 20 µg/dL (0.39-0.97 µmol/L), (2) identified lead on the surfaces within the residence (X-ray fluorescence reading > 2.0 mg Pb/cm^2 or in house dust ([> 1500 µg/g]), or (3) an older sibling in the residence with a blood lead > 10 µg/dL. Primary interior and exterior activity areas were identified through discussions with care-givers about where the participating child spent time, and from visual clues observed by the CLEARS technicians. After obtaining informed consent some of the subjects were randomized into two groups: one participated in a scheduled cleaning intervention and lead education program during the study, (called the Lead Intervention in the text) and the other was a control which received accident prevention education (called the Accident Intervention in the text) (Rhoads and Lioy, 1992; Rhoads et al., 1997).

All of the consenting subjects were included in at least some of the analyses presented in this manuscript. However, only those included in the Lead Intervention or the Accident Intervention are used in the analyses conducted by Rhoads et al., 1997.

WIPE AND VACUUM SAMPLING TECHNIQUES

Wipe and vacuum samples were collected from primary interior activity areas in all homes, including bedrooms, the main living room, the kitchen, and window sills (wipes only). Sampling was conducted before the start of the cleaning intervention, and one or two more times during the study.

Dust on smooth surfaces accessible to children was sampled using the LWW dust wipe sampling technique. The LWW employed a set of three round polyethylene filters mounted on a replaceable non-skid rubber surface attached to the sampling block (Lioy et al., 1993). A sample was collected on flat surfaces. Most samples were collected with a 100 cm^2 template while some (usually those collected on narrow surfaces) were collected with a 50 cm^2 template. Each filter was employed individually with the first and second filters being wetted with deionized water. Each wetted filter was gently shaken to remove excess liquid, placed on the sampling block, and moved back and forth three times across areas demarcated by the template. Dust piles created by pushing the block during the first two wipes were collected by placing the second or the third filters on top of any piles. Wipe samples collected using the LWW were taken on the floors in the primary activity microenvironments, or from interior window sills. Side by side wipe samples were collected with every tenth sample using an area with similar surface characteristics and adjacent to the first sampling location. The test results were reported by Adgate et al. (1995), using the common metrics of dust loading (g/m^2) and lead loading (mg/m^2). They found a coefficient of variation (CV) of 19% and 10% for the values of dust loading on floors and sills, respectively, and 23% and 43% for lead loading on floors and sills, respectively.

Vacuum samples of dust were collected using a vacuum with an in line filter, and were obtained from wall to wall carpets and area rugs with surface areas > 48 ft^2. This technique was previously described by Wang et al. (1995). The carpets were sampled by moving the vacuum nozzle back and forth three times in an overlapping pattern within a 0.25 m^2 template. The vacuum had a flow rate of 1.7 m^3/min, and an inlet velocity of 13.5 m/sec. Prior to analysis, dust samples were passed through a 500 μm sieve to remove coarse carpet fibers, insect bodies, and other large materials. The amount of dust estimated to be in the carpet was calculated from the amount collected after applying adjustments for the effect of temperature and humidity on vacuum sampling efficiency using the algorithm developed by Wang et al. (1995).

Filters were dried and weighed pre- and post- sampling in a temperature and relative humidity controlled environment. All collected samples were digested in 19% spectrograde (LWW) or reagent grade (vacuum samples) nitric acid in a laboratory microwave system (CEM MDS 200, Matthews, North Carolina) using an U.S. Environmental Protection Agency (USEPA) Soil Sample Protocol (USEPA, 1991). Wipe samples were analyzed using either a graphite furnace atomic absorption spectrophotometer (GFAA, Perkin Elmer), or inductively coupled plasma-mass spectroscopy (ICP-MS; Fisons Plasma Quad PQS). Vacuum samples were analyzed using Flame Atomic Absorption Spectroscopy (FAA: Perkin Elmer model 3100). Calibration standards were all traceable to National Institute of Standards and Technology (NIST) Standards. NIST reference materials 2709 and 2711 were used as quality assurance checks for all dust samples. Sample digestion blanks, reagent blanks, and lead solution spikes were included in all analytical runs. All samples measured by the GFAA, and greater than 10% of samples measured by the FAA and ICP-MS were evaluated for system spike recovery. The detection limit of the FAA was approximately 0.5 ppm, the GFAA was approximately 10 ppb, and the ICP-MS had a detection limit of 1 ppb. For both the wipe samples and the vacuum samples acceptable instrument error was within 20%; although, most QC analyses were within 10%.

Parallel experiments to establish the potential influence of sources on the children's blood lead levels, required samples of exterior residential soil and street dust to be collected near a subset of homes (Adgate, 1996). In addition, a subset of homes was sampled for lead in indoor air and/or tap water (Rhoads et al., 1997).

CLEANING PROTOCOL

The homes in the randomized Lead Intervention received dust control service at least 10 times in two thirds of the homes, and less than 10 times in one third of the homes over a 9–15 month period. The variability was caused by failure of some participants to be available for scheduled appointments, and the cancellation of visits due to winter storms. The intervention commenced as soon as possible after randomization (Rhoads et al., 1997). Home dust control was carried out by a CLEARS crew of two persons (non-scientists or previously employed technicians) who were trained in practical ways to reduce lead contamination in the home. The home cleaning staff discussed the play and activity habits of each young child with their mother, and special care was given to clean dust in these areas. Floors and smooth surfaces were cleaned with water and a household detergent (Spic and Span®). A high phosphate detergent was not used since it is illegal in New Jersey. Rugs and carpets were cleaned with a high efficiency particle air (HEPA) filter vacuum cleaner. Efforts were made to involve the family in the cleaning to give them a degree of control in this important area of their home life. In addition, family members were encouraged to remove loose paint in accessible areas, and make repairs with simple wet scraping and repainting of surfaces.

SAMPLING PROTOCOL

House dust samples were acquired in all participating homes during the CLEARS. Initial (First Visit) samples were obtained at the time of recruitment, which commenced during 1992. The protocol called for additional sampling once more during the cleaning intervention period and again at the conclusion of the interventions. This approach provided the opportunity to establish a record of the changes in potential lead exposure for each participating home. Samples were collected in multiple rooms to assess potential exposure in different parts of the residence where a lead burdened child spent a large fraction of the time. Such information, along with questionnaire data, was essential for use by Rhoads et al. (1997) in analyses to examine the mechanisms that affected blood lead levels found in children living in Lead Intervention homes.

The dust sampling approach used in CLEARS is derived from the previous dust sampling studies conducted by Lioy et al. (1992) and Freeman et al. (1995). They showed that too more accurately understand the nature of house dust, a measurement must include both the concentration of the contaminant in the dust, and the loading of the dust on or within a surface. The former will represent proximate and/or ultimate sources of lead, and the latter will provide information on the short term or long term loading of the dust on a surface. The CLEARS screening data set collected by Adgate et al. (1995) showed that in homes potentially available for randomization, the lead loading was more variable than the dust loading on all three surfaces examined: floors, window sills and carpets. The lead concentration data obtained in the screened homes were compared with the New Jersey residential lead soil standard and it was found that 60% of the residences had levels above 400 μg/g limit (NJ Dept. of Environmental Protection, 1994). These analyses established that many homes initially selected for use in the randomized trial had the potential for yielding significant lead exposures because of the high lead levels present on surfaces in each residence.

RESULTS

The entire CLEARS microenvironmental data set was used to first describe the overall distribution patterns of dust and lead in the residences selected as part of both participant groups. The summary statistics for the ensemble of all the wipe samples, Table 1, had a geometric mean lead concentration of 603 μg/g . The peak concentration was above 7,500 μg/g of dust, Figure 1a. The distribution for dust and lead loading, and lead concentration were log - normally distributed, Figure 1a, with the lead loading (μg/m^2) having the highest geometric standard deviation.

The vacuum samples from the rugs showed a different result, Table 1 and Figure 1b. In this instance, the lead concentration had a geometric mean of 502 μg/g, (peak concentration was 35,600 μg/g), but both the dust loading and the lead loading values, were about an order of magnitude higher than the values obtained by the wipe samples.

TABLE 1. General Log Normal Distribution Parameters for all Wipe Samples and Vacuum Samples Obtained During the Course of CLEARS: Dust Loading, Lead Loading, Lead Concentration

Vacuum Samples	n	Geo. Mean	Geo SD
Dust loading	516	6.65 g/m^2	3.3
Lead loading	516	3.35 mg/m^2	5.0
Lead concentration	516	502 μg/g	3.0
Wipe Samples	n	Geo. Mean	Geo. SD
Dust loading	1731	0.47 g/m^2	2.9
Lead loading	1733	0.28 mg/m^2	4.5
Lead concentration	1731	603 μg/g	3.0

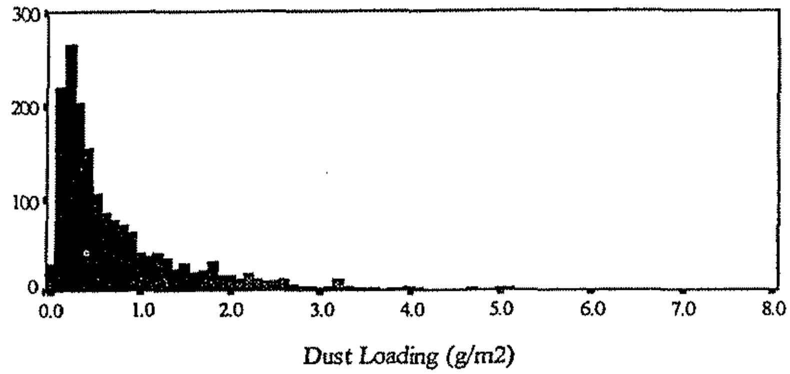
Sampling Results From All Participating Homes

Wipe Samples. To begin assessing whether differences in lead loading, lead concentration, and dust loading existed between the homes participating in the two randomized groups, data were examined from homes where there were at least two sampling visits, and in some cases three sampling visits. Lead concentration, lead loading and dust loading derived from wipe samples taken in each residence during sampling visits 1, 2, and possibly 3 are shown in Table 2a. The geometric mean lead concentration and lead loadings measured during the second and third sampling visit in each Lead Intervention home were lower than the levels observed in Accident

Figure 1

The CLEARS Wipe Samples

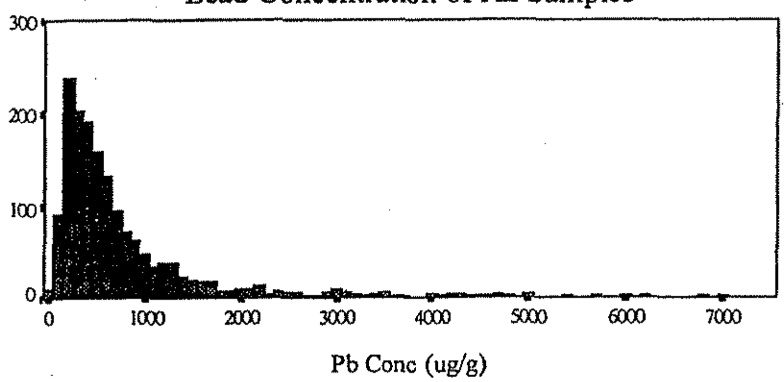
Dust Loading of All Samples



n=1731
GM=0.47 g/m^2
GSD=2.9

The CLEARS Wipe Samples

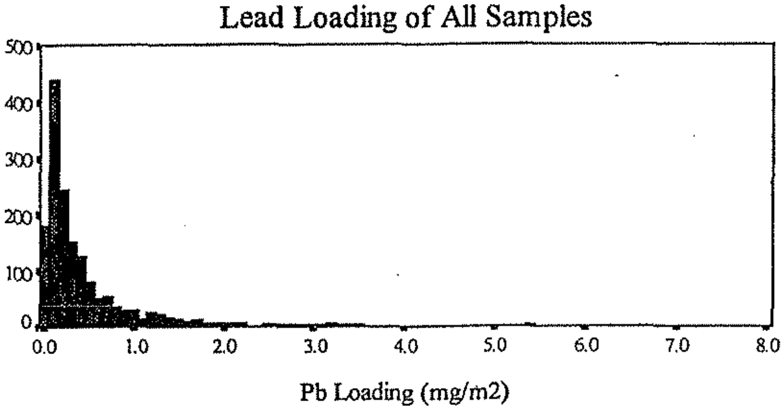
Lead Concentration of All Samples



n=1731
GM=0.28 mg/m^2
GSD=4.5

The CLEARS Wipe Samples

Lead Loading of All Samples



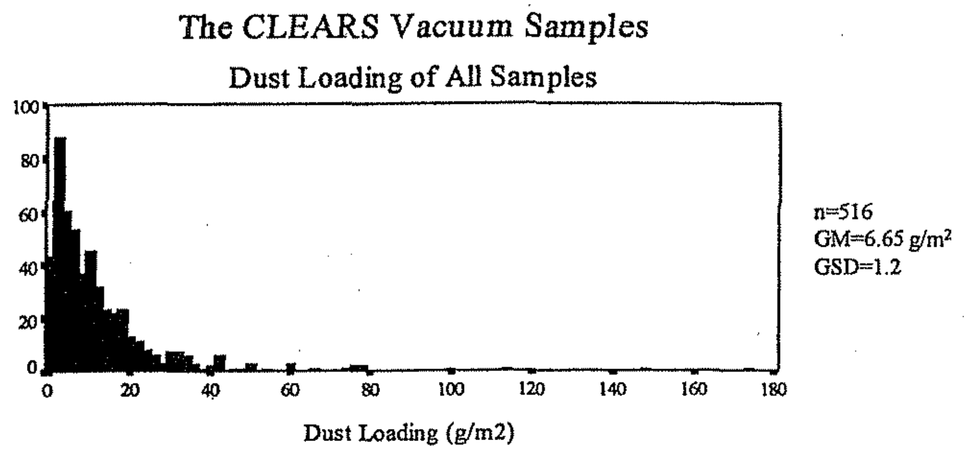
n=1733
GM=602.5 µg/g
GSD=4.5

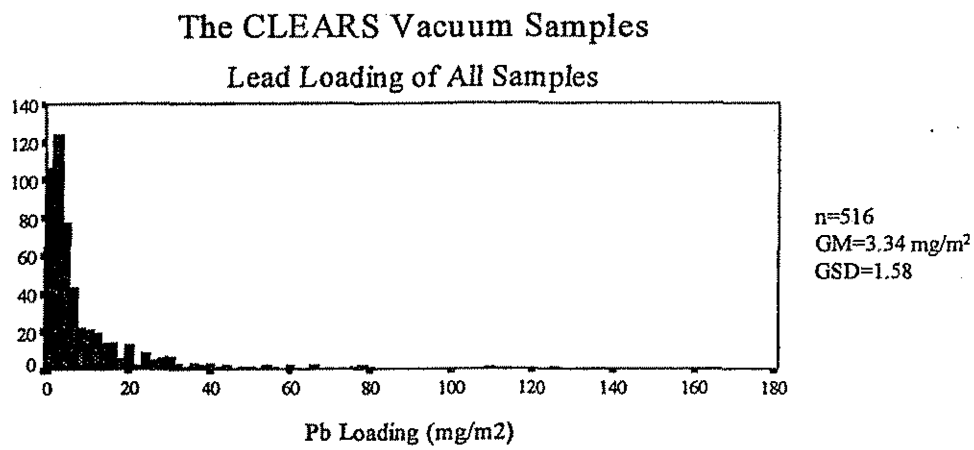
TABLE 2. The Distributional Statistics for Wipe Samples and Vacuum Samples of Homes Participating in the Accident Prevention (Lead Controls) and Lead Cleaning Intervention Groups of CLEARS: Having Two or Three Visits for Sampling

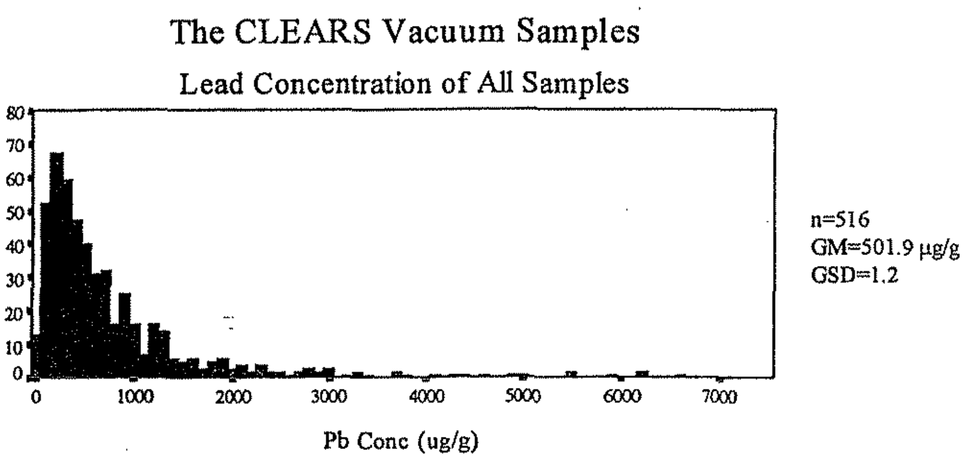
	Visit 1			Visit 2			Visit 3		
Wipe Sampling (Total-Undifferentiated by RoomType)	N	GM	GMSD	N	GM	GMSD	N	GM	GMSD
Cleaning intervention									
Dust loading (g/m^2)	201	0.49	3.0	201	0.41	2.9	113	0.35	2.6
Lead loading (mg/m^2)	201	0.31	4.7	201	0.24	4.1	113	0.17	3.7
Lead concentration (μg/g)	201	633	3.4	201	570	3.2	113	484	2.7
Accident prevention									
Dust loading	203	0.46	3.0	200	0.49	2.9	138	0.40	2.9
Lead loading	203	0.31	4.0	200	0.38	4.7	138	0.26	4.1
Lead concentration	203	673	2.7	200	783	3.1	138	652	2.5
Vacuum Sampling									
Cleaning intervention									
Dust loading	80	9.00	2.9	72	5.78	3.1	35	2.90	3.4
Lead loading	80	4.47	4.0	72	2.80	5.0	35	1.53	4.2
Lead concentration	80	497	2.9	72	485	3.2	35	526	2.6
Accident prevention									
Dust loading	80*	6.35	3.1	81	6.12	3.9	36	7.64	4.3
Lead loading	80	3.51	3.6	81	2.51	5.6	36	2.98	6.0
Lead concentration	80	553	2.8	81	410	2.3	36	390	3.0

* = One mass sample lost.
GM = Geometric man.
GMSD = Geometric standard deviation.

Figure 2


The CLEARS Vacuum Samples
Dust Loading of All Samples
Dust Loading (g/m2)
n=516
GM=6.65 g/m²
GSD=1.2


The CLEARS Vacuum Samples
Lead Loading of All Samples
Pb Loading (mg/m2)
n=516
GM=3.34 mg/m²
GSD=1.58


The CLEARS Vacuum Samples
Lead Concentration of All Samples
Pb Conc (ug/g)
n=516
GM=501.9 µg/g
GSD=1.2

Intervention homes. The lead loading values were lowered by 37% and 35%, for the second and third visit respectively, and the lead concentrations were reduced by 27% and 24%; respectively. These results were analyzed for statistical significance using a t-test on the logarithms of the distributions (log-normal). Each of the Lead Intervention GM's were statistically significant and different from Accident Intervention values with p-values of 0.001 and 0.011 for loading, and 0.006 and 0.016 for concentrations, respectively. The percent declines between the second and third visit data, however, are not directly comparable because it was not possible to make three sampling visits to all homes. The dust loadings were lower but not statistically lower in the Lead Intervention homes, as compared to the Accident Intervention homes after the second and third visits.

Vacuum samples. The vacuum sample results obtained from the Accident Intervention homes showed slight decreases in lead concentration for the second and third visits, Table 2b. In contrast, a decrease in the geometric mean lead loadings collected from the rugs in the Lead Intervention homes was observed by the third visit. For example, the lead loading decreased from visit 1 to 2 in both Accident Intervention and the Lead Intervention homes. Yet, by the third visit the Lead Intervention homes continued to show declines, and the lead loadings in the Accident Intervention homes increased. The decline in levels, however were not statistically significant; $p = 0.087$, $n = 36$.

The effectiveness of the HEPA filter vacuum cleaner in removing dust from the rugs in the Accident Intervention and the Lead Intervention homes are also illustrated in Table 2b. Over the course of CLEARS there was no net reduction in dust loading between the first and second or the first and third sampling visits among the Accident Intervention homes. Contrast these values with the progressive decline in dust loading in the Lead Intervention homes. The decline resulted in greater than 2.5X lower geometric mean dust loadings for the third visits when compared with the values obtained for Accident Intervention homes. However, this analysis must be viewed with caution because each visit had different values for n.

Results For The Subset Of Homes With Three Sampling Visits

To obtain a better picture of the efficacy of the home Lead intervention throughout CLEARS the data were stratified to include only those homes in which three sampling visits were made over the course of the one year Lead Intervention. Disaggregation of the data set was again done by vacuum sample, wipe sample, and visit number; however, the wipe sampling results were further differentiated into window sills and room type. The latter was done to maintain coherence of either source type or common activities. The analyses were conducted only for the homes in each participant group that had sampling data from a particular surface for all three visits. The geometric mean and standard deviation of the distribution analyses for the refined dust loading, lead loading and lead concentration data set are shown in Tables 3, 4, and 5, respectively.

The vacuum sampling results for the Accident Intervention homes showed a 40% increase in geometric mean dust loading over the course of the entire three visit sampling period. In contrast, homes that were part of the Lead Intervention portion of the study showed a consistent decline in geometric mean vacuum dust loading. The net decline among the 31 rugs sampled three times, illustrated in Figure 3, was 71%, which was statistically significant in a one-way Analysis of Variance (ANOVA), $p = 0.05$.

TABLE 3. Dust Loading on Carpets and Surfaces for All Residences with Sampling Conducted Three Times Sequentially Over the Course of CLEARS in Either the Lead Intervention or the Accident Intervention Homes

Vacuum Sampling				Wipe Sampling			
Accident Intervention (g/m²)				Accident Intervention (g/m²)			
Visit #	n	GM	GM-STD	Visit #	n	GM	GM-STD
				Bedroom			
1	33	4.89	3.3	1	27	0.37	2.7
2	33	5.57	5.0	2	27	0.43	3.3
3	33	6.88	4.4	3	27	0.36	2.5
				Living Room			
				1	21	0.29	3.3
				2	21	0.31	2.7
				3	21	0.33	2.5
				Window Sill			
				1	35	0.66	2.9
				2	35	0.56	2.8
				3	35	0.53	2.8
				Kitchen			
				1	17	0.34	2.5
				2	17	0.34	2.0
				3	17	0.29	4.1
Lead Intervention (g/m²)				Lead Intervention (g/m²)			
				Bedroom			
1	31	10.7	2.7	1	22	0.49	2.6
2	31	5.7	3.3	2	22	0.32	2.4
3	31	3.1	3.3	3	22	0.32	2.8
				Living Room			
				1	14	0.30	3.9
				2	14	0.50	2.6
				3	14	0.60	2.1
				Window Sill			
				1	27	0.75	2.2
				2	27	0.32	3.0
				3	27	0.29	2.2
				Kitchen			
				1	21	0.33	2.2
				2	21	0.29	2.7
				3	21	0.30	2.7

Note: GM-Geometric Mean
STD-Standard Deviation

TABLE 4. Lead Loading on Carpets and Surfaces for All Residences with Sampling Conducted Three Times Sequentially Over the Course of CLEARS in Either the Lead Intervention or the Accident Intervention Homes

Vacuum Sampling Accident Intervention (mg/m^2)				Wipe Sampling Accident Intervention (mg/m^2)			
Visit #	n	GM	GM-STD	Visit #	n	GM	GM-STD
				Bedroom			
1	33	3.21	3.3	1	27	0.21	2.2
2	33	2.74	5.0	2	27	0.35	3.7
3	33	2.69	6.0	3	27	0.20	2.5
				Living Room			
				1	21	0.15	4.1
				2	21	0.18	3.0
				3	21	0.19	2.7
				Window Sill			
				1	35	0.52	3.7
				2	35	0.55	4.7
				3	35	0.53	4.7
				Kitchen			
				1	17	0.23	3.0
				2	17	0.34	2.0
				3	17	0.13	4.5
Lead Intervention (mg/m^2)				Lead Intervention (mg/m^2)			
				Bedroom			
1	31	4.94	3.7	1	22	0.24	4.2
2	31	3.72	5.6	2	22	0.13	3.6
3	31	1.71	4.1	3	22	0.12	3.5
				Living Room			
				1	14	0.16	3.4
				2	14	0.15	2.4
				3	14	0.18	2.3
				Window Sill			
				1	27	0.69	4.9
				2	27	0.26	3.6
				3	27	0.18	4.0
				Kitchen			
				1	21	0.13	5.0
				2	21	0.13	4.1
				3	21	0.12	3.3

Note: GM-Geometric Mean
STD-Standard Deviation

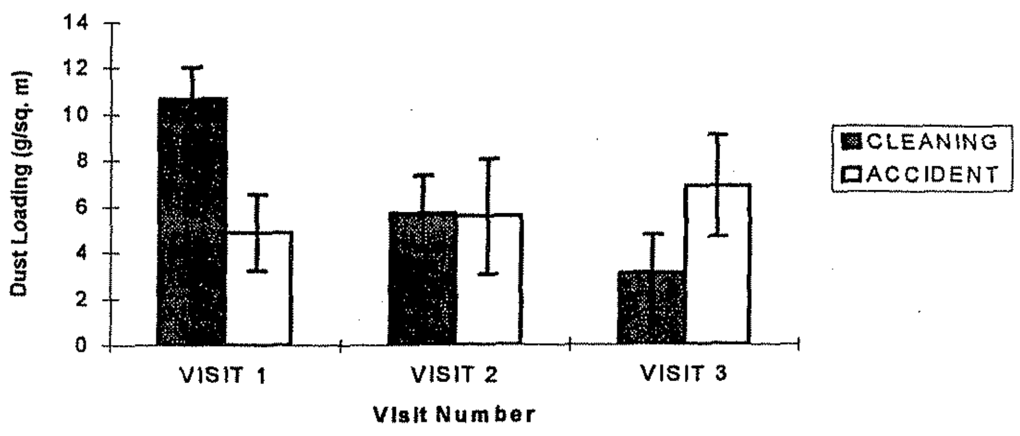
TABLE 5. Lead Concentration on Carpets and Surfaces for All Residences with Sampling Conducted Three Times Sequentially Over the Course of CLEARS *in Either the Lead Intervention or the Accident Intervention* Homes

Vacuum Sampling Accident Intervention (μg/g)				Wipe Sampling Accident Intervention (μg/g)			
Visit #	*n*	*GM*	*GM-STD*	Visit #	n	GM	GM-STD
				Bedroom			
1	33	657	2.5	1	27	559	1.8
2	33	492	3.3	2	27	822	3.0
3	33	391	3.0	3	27	564	2.0
				Living Room			
				1	21	514	2.7
				2	21	589	1.8
				3	21	569	1.8
				Window Sill			
				1	35	786	3.0
				2	35	967	4.2
				3	35	1008	2.9
				Kitchen			
				1	17	710	1.6
				2	17	615	2.7
				3	17	478	2.5
Lead Intervention (μg/g)				Lead Intervention (μg/g)			
				Bedroom			
1	31	464	3.0	1	22	660	3.3
2	31	661	3.7	2	22	385	2.2
3	31	545	2.7	3	22	382	2.0
				Living Room			
				1	14	540	3.7
				2	14	275	2.0
				3	14	320	1.9
				Window Sill			
				1	27	915	4.2
				2	27	836	3.8
				3	27	642	4.2
				Kitchen			
				1	21	411	3.3
				2	21	428	2.2
				3	21	408	2.2

Note: GM-Geometric Mean
STD-Standard Deviation

Figure 3

Mean Dust Loadings of Vacuum Samples for Houses Visited 3 Times



There was a statistically significant (ANOVA, $p = 0.05$) decrease in the geometric mean dust loading of 35% and 70% obtained from the bedrooms and the window sills, respectively, in the Lead Intervention homes. No significant change in dust loading was observed in the kitchen. There was a 50% increase in dust in the living room. One observation in the Lead Intervention homes was that the dust loadings in the bedroom and on the window sills decreased to approximately 0.3 g/m^2, which was similar to the value obtained in the kitchen throughout the intervention. The only measurable change in dust loading in the Accident Intervention homes observed between visits 1 through 3 on sampled surfaces was a 20% decline on the window sills. In the Accident Intervention homes, there were no differences among the measured geometric mean wipe sample lead loadings when the first visit values were compared with the third visit loadings. A one-way ANOVA ($p = 0.05$) completed on the data found that none of the means from visit 2 or 3 were statistically different from the value obtained during the first visit. There was, however, an increase in lead loading between the first and second for both the kitchen and the bedroom visit which decreased back to the first visit values during visit three.

The homes participating in the Lead Intervention showed a statistically significant decline in the geometric mean lead loadings on the window sills of 75% (one-way ANOVA, $p = 0.05$), and in the bedrooms there was a 50% decline. The bedrooms recorded all of the reduction between the first and second visit. In contrast, the living room results showed a small increase in lead loading over the course of the intervention period, which was similar to the increases observed for dust loading.

The lead concentrations illustrated a different pattern. None of the homes in either the Accident Intervention or the Lead Intervention portion of the study participated in a long term remediation program while samples were being taken during CLEARS. Therefore, the primary means for reducing the concentration were either dilution with dust from another origin, or the lack of current input from a source that had historically contributed to the lead loading. Increases could be associated with a new source, increased flux from a current source of lead, or the selective removal of recently accumulated dust with low lead content.

The vacuum samples taken in the Accident Intervention homes showed a decrease in the lead concentration. Since the dust loading increased while the lead loading increased, the decrease in lead concentration would be associated with an increase of non-lead related dust in the carpet. There was an increase in the lead concentration in the window sill in Accident prevention homes. This could be due to removal of non-lead laden surface dust during the first visit.

The lead concentration fell off modestly in all the wipe samples collected from the bedrooms, living rooms and window sills in the Lead Intervention homes. This was true when the second and/or third samples were compared with the initial wipe sample values. The vacuum samples did not yield a similar result. In fact, although the actual geometric mean dust and lead loadings went down, the lead concentrations present in the second and third vacuum samples were higher than those found in the initial Lead Intervention homes vacuum samples. This latter point suggests an uneven distribution of lead among the particles retained in various depths of the rug and carpets in these homes.

The efficacy of the Lead Intervention can be further documented from the percentage of the Lead Intervention program for homes that had lead reductions in the wipe samples taken from the individual rooms. The analysis found a reduction in lead loading for 75%, 81%, and 68% of the bedrooms, window sills, and kitchen floors, respectively. The vacuum samples collected in the same group of Lead Intervention homes found that 78% of the rugs and carpets had reductions in lead loading.

DISCUSSION

The analysis of the vacuum and wipe sampling data, and the comparisons between the Lead Intervention program homes and the Accident Intervention homes in the CLEARS indicated that a thorough cleaning program conducted over the course of a year will reduce the geometric mean of the dust and lead loading. This is true for both vacuuming of rugs, and cleaning of exposed surfaces. For the rugs, the decrease in lead and dust loading was substantial (> 75%) and progressed throughout the study. The result was consistent with the preliminary studies of Roberts et al. (1995) which indicated that intensive cleaning was necessary to begin to remove lead deeply embedded in a rug. The results, however, do not support the laboratory results of Ewers et al. (1994) which indicated that vacuuming does poorly in removing embedded lead from used rugs.

For the exposed surfaces in the bedroom and the window sills, the major change in lead loading occurred between the first and second period of sampling. The loading either deceased slightly or remained stable between the second and third sampling periods. These differences in rate of decline to a stable level are probably due to the presence of a lead reservoir in the rugs or direct deposition by other sources. In the Accident Intervention homes the wipe sampling results did not show any consistent trends over time for any surface type.

A surprising result derived from the wipe sample data was that the concentration of the lead in the dust went down over time. The suggestion here is the presence of historically high lead loadings on the surfaces prior to the first sampling visit, and before the start of the home Lead Intervention. The values could have been derived from a particular source, e.g., automotive exhaust, or series of events that deposited lead enriched dust, e.g., deterioration of a wall, or periodic tracking of lead indoors. The concentration of the lead (μg/g) in samples taken in the Accident Intervention homes decreased, although, the lead loading remained relatively constant. This appeared to be due to the increase in the non-lead laden dust on Accident Intervention homes surfaces.

Based upon the microenvironmental sampling and analysis of lead in house dust, it is apparent that a Lead Intervention will significantly reduce the geometric mean lead loadings in rugs and on surfaces that can be touched by a child. This should result in less lead adhering to a child's skin, objects used for play, or food consumed while at play (National Research Council, 1993). Thus, it would be possible to have the actual exposure and internal dose decline in the children participating in CLEARS Lead Intervention group. This has been documented in a manuscript by Rhoads et al. (1997) for the children participating in the Lead Intervention. There was a mean reduction in blood lead values of 2.2 μg/dL for the children from the Lead Intervention homes and < 0.17 μg/dL for the children in the Accident Intervention homes. The CLEARS findings are supported by previous work conducted by Davies et al., 1990, and Hilts et al., 1995 which indicated that lead loading on carpets and surfaces where children play is the best indicator of the lead level present in the blood of infants.

The study also showed that a consistent cleaning protocol, and, as a logical extension, prevention of exposure must focus on cleaning locations where a child participates in indoor activities, and contacts lead burdened surfaces. Further, rugs and other freely accessible surfaces must be cleaned or periodically replaced (e.g. throw rugs) to reduce the total potential lead burden in a child. This is necessary since it is possible that contamination on surfaces, such as tables, cannot be effectively reduced below a baseline value, which would be some function of the general characteristics of the home environment. This point is supported by (1) the difficulty in reducing the geometric mean lead loading of the wipe samples below 0.12 mg/m^2 in the kitchens and the living rooms of the Lead Intervention homes, and (2) reductions in the bedroom and on the window sills had trends toward the mean of 0.12 mg/m^2. A similar phenomenon was observed for dust loading.

Finally, two aspects of the CLEARS protocol suggest that it should be possible to implement a modified cleaning strategy for use by families with lead burdened homes to reduce exposure. First, the personnel trained for the CLEARS were not scientists or prior members of the EOHSI technical staff. Second, the CLEARS employed many readily available methods and materials to conduct the intervention. The most sophisticated item was the HEPA vacuum cleaner, and in recent years a number of manufacturers are producing commercial models that are in a price range (< $400.00) that is affordable by the general public.

CONCLUSIONS

The Lead Intervention significantly reduced the levels of house dust and lead in rugs, and on flat surfaces, floors and window sills. The most significant declines in both house dust and lead loadings occurred on rugs cleaned using a HEPA vacuum cleaner. This was probably due to the large reservoir of lead available in the rugs before the Lead Intervention commenced. The dust and lead loading on flat surfaces declined to respective equilibrium values. These are presumably due to the current flux of dust and lead laden dust into and within the home from a variety of sources.

A vacuum cleaning and dust wipe protocol can be used for assessing the changes in lead loading, lead concentration, and dust loading in microenvironments, and are effective indicators of long term reductions in exposures. The lead concentration information is critical for examining changes caused by the addition or elimination of proximate or ultimate sources of lead.

ACKNOWLEDGMENTS

The authors wish to thank the entire CLEARS field and study design team for their efforts in completing the many components of the Study. Included are Adriene Ettinger, Marta Jimenez, Dr. Eugene Wang, Dr. Brian Buckley and Dr. Natalie Freeman. We also want to thank the members of the Jersey City Lead Poisoning Prevention Program for their efforts in establishing the study population, and all the participating families. We also appreciate the major contributions and comments made by Dr. Timothy Buckley, the USEPA project officer. The Research has been funded in part by cooperative agreement CR820235 with the National Exposure Research Laboratory of the Environmental Protection Agency, by an interagency agreement from the National Institute of Child Health and Human Development, and by grant #18152 from the Robert Wood Johnson Foundation. Drs. Lioy, Weisel, and Rhoads are supported in part by the NIEHS Center (ES05022-06). Although the research described in this article was funded in part by the USEPA, it has not been subjected to Agency review, and does not necessarily reflect the views of the Agency, and no official endorsement should be inferred.

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Manuscript Received: November 19, 1996
Manuscript Accepted: April 25, 1997