Multiple Metal Contamination from House Paints: Consequences of Power Sanding and Paint Scraping in New Orleans

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Power sanding exterior paint is a common practice during repainting of old houses in New Orleans, Louisiana, that triggers lead poisoning and releases more than Pb. In this study we quantified the Pb, zinc, cadmium, manganese, nickel, copper, cobalt, chromium, and vanadium in exterior paint samples collected from New Orleans homes (n = 31). We used interior dust wipes to compare two exterior house-painting projects. House 1 was measured in response to the plight of a family after a paint contractor power sanded all exterior paint from the weatherboards. The Pb content (~130,000 µg Pb/g) was first realized when the family pet died; the children were hospitalized, the family was displaced, and cleanup costs were high. To determine the quantity of dust generated by power sanding and the benefits of reducing Pb-contaminated dust, we tested a case study house (house 2) for Pb (~90,000 µg/g) before the project was started; the house was then dry scraped and the paint chips were collected. Although the hazards of Pb-based paints are well known, there are other problems as well, because other toxic metals exist in old paints. If house 2 had been power sanded to bare wood like house 1, the repainting project would have released as dust about 7.4 kg Pb, 3.5 kg Zn, 9.7 g Cd, 14.8 g Cu, 8.8 g Mn, 1.5 g Ni, 5.4 g Co, 2.4 g Cr, and 0.3 g V. The total tolerable daily intake (TTDI) for a child under 6 years of age is 6 µg Pb from all sources. Converting 7.4 kg Pb to this scale is vexing—more than 1 billion (10^9) times the TTDI. Also for perspective, the one-time release of 7.4×10^9 µg of Pb dust from sanding compares to 50×10^9 µg of Pb dust emitted annually per 0.1 mile (0.16 km) from street traffic during the peak use of leaded gasoline. In this paper, we broaden the discussion to include an array of metals in paint and underscore the need and possibilities for curtailing the release of metal dust. *Key words*: Cd, Co, comparison of paint and gasoline as Pb sources, Cr, Cu, dust control, dust wipe, metal contents of old paint, Mn, Ni, Pb, sanding old paint, scraping paint, Zn, V.
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New Orleans, Louisiana, is an old city with architecturally distinguished wood houses that were mostly constructed pre-1950 when lead-based paints were in common use (*1*). In the United States, about 10 million metric tons of Pb went into paint products and antiknock additives for gasoline (*2*). The removal of Pb from gasoline resulted in a phenomenal reduction of childhood Pb exposure (*3*). Now, policy emphasis is on the residential reservoir of deteriorated Pb-based paint, Pb-contaminated dust, and Pb-contaminated residential soil (*4*).

Many homeowners understand the importance of maintenance but remain ignorant or confused about Pb hazards. They rely upon professional painters, salespersons, or contractors, who often do not have the knowledge, expertise, or willingness to clearly communicate the consequences of improper removal of old Pb-based paints (*5*). The basic question is whether families with young children can safely inhabit and maintain old homes coated with Pb-based paint.

A New Orleans couple with three healthy children (ages 4 years, 2 years, and 1 year) and a family pet hired a professional painting company to repaint the exterior surface of their two-story, wood frame house built in 1925 (house 1): the painter's contract specified pressure washing and machine sanding. Pb was never discussed. After 6 weeks of unconfined power sanding of several thousand square feet of cypress weatherboards, the family pet died. The veterinarian, familiar with house renovation hazards to pets, was the first to discuss Pb. Shortly thereafter, the three children were hospitalized for 4 days at a cost of $10,000, the family was displaced from the home, and a $70,000 cleanup effort began (*6*).

Table 1 and Table 2 illustrate the condition of the house immediately after sanding exterior paint containing ~130,000 µg Pb/g to bare wood and the gradual improvement of interior conditions during the cleanup. The current U.S. Environmental Protection Agency (U.S. EPA) standards for house dust are 40 µg/ft^2 for floors and 250 µg/ft^2 for windowsills (*4*). [Empirical research suggests that the standard for floors should be 15 µg/ft^2 (*7*).] After repeated vacuuming (vacuum contained a HEPA filter), mopping (three-bucket procedure), and dusting with a tack cloth, the numbers on 28 July 1999 remained elevated. Discouraged, the family discarded all contaminated cloth, objects, and small appliances that could not withstand fastidious cleaning. All interior surfaces were painted to lock down remaining dust. Porous wood and floor surfaces were cleaned and then sealed. Window air-conditioning units were replaced. Pb-specific detergent was used to pressure wash porches, a brick patio, and concrete. Mats were placed at doorways where shoes were removed. The interior wipe samples collected on 10 February 2000 show remarkable improvements in the interior of the house.

Pb on the property remained high, with bare soils varying from 360 to 3,900 µg/g. The U.S. EPA Pb standards for soil are 400 µg/g for bare soils of play areas and 1,200 µg/g average for all other bare areas of the residential environment (*4*). [Our empirical research of the association between soil Pb and children in New Orleans suggests that 80 µg Pb/g soil provides a more appropriate margin of safety for children (*8*).] The parents encouraged the children to play on grassy areas and plan to replace or cover bare soil with clean soil in the near future. The interior Pb-dust loading of the family home (Table 1, Table 2) illustrates the hazard of sanding old Pb-based paint. The amount and severity of contamination raises questions about how to manage and improve the

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safety of exterior paint renovation on old houses. To develop understanding of the issue, we set out to evaluate the Pb as well as the zinc, cadmium, manganese, nickel, copper, cobalt, chromium, and vanadium content of paint samples from 31 houses in New Orleans. We then conducted a case study on a house (house 2) to test whether scraping is a safer method for renovating Pb-based paint than power sanding because it reduces the amount of dust released.

A family of two adults and two children (ages 33 months and 12 months), who lived near the paint-sanding project, was preparing to hire a paint contractor to sand their house (house 2). They were acquainted with the family who lived in house 1, which was power sanded. After learning that they too had Pb-paint, the family who live in house 2 decided to seek another method of exterior house renovation. With the full cooperation of the family, we used the house as a case study site to evaluate scraping as a method for paint renovation. The Pb content of the paint measured ~90,000 µg Pb/g. According to the Louisiana Department of Environmental Quality (Baton Rouge, LA), interim control of Pb-based paint is a system of management that minimizes the release of Pb dust and does not involve the total removal of Pb-based paint. The exterior siding of the two-story, wood frame house built in the 1920s was coated with deteriorating paint with chips that were falling to the ground. The family agreed to hire a painter who would not power sand, but instead would hand scrape the deteriorated paint to prepare the exterior siding for painting. The family was given a copy of *Lead Paint Safety: A Field Guide for Painting, Home Maintenance, and Renovation Work* (*9*) and encouraged to vacuum and wet-mop frequently. The family owned a good household vacuum cleaner that was efficient but not HEPA rated. We selected key health and environmental measures to evaluate the effectiveness of the interim controls before, during, and after renovating the exterior Pb-based paint on the house. These measures included determination of blood Pb (BPb), paint analysis, renovation preparation, dust and soil sample collection, and analysis methods.

Materials and Methods

Blood Pb. Blood was drawn from the two case study children by the children's pediatrician during a regular medical appointment in May before the work was started; a second test was performed in October after the project was completed. Venipuncture, the preferred method for measuring Pb, could only be used to test the older child (33 months of age). Because of difficulty in locating a suitable vein for venipuncture, the finger-stick method was used with the 12-month-old child. The pediatrician's contract laboratory analyzed the blood samples for Pb.

Paint extraction and analysis. We collected paint samples from the case study house (house 2) and 30 other houses throughout the city ($n = 31$). The paint chips were ground into a fine powder using a porcelain pestle and mortar. Then, 0.250 g sample duplicates were weighed into a 50-mL polypropylene centrifuge tube. Concentrated trace-metal–grade nitric acid (5 mL) was added to each sample. The paint and acid were mixed and allowed to react for 20 hr. Then, 18 $M\Omega\ cm^{-1}$ deionized water (Fisher Scientific, Pittsburgh, PA) was added to fill the tubes to 25 mL. Samples were placed in a reciprocating shaker for 1 hr at room temperature. After shaking, 18 $M\Omega\ cm^{-1}$ deionized water was added to fill the tubes to 50 mL. The tubes were then centrifuged for 5 min at $1,000 \times g$. Finally, the samples were filtered and measured with an inductively coupled plasma atomic emission spectrometer (ICP-AES) calibrated with National Institute of Standards and Technology (NIST; Gaithersburg, MD) certified standards. The samples were measured for Pb, Zn, Cd, Mn, Ni, Cu, Cr, Co, and V.

Scraping paint from the house. We informed the painting contractor about the quantity of Pb in the paint and provided a copy of *Lead Paint Safety: A Field Guide for Painting, Home Maintenance, and Renovation Work* (*9*). He agreed not to use a power sander, but to perform scraping by hand to remove the loose and deteriorated paint chips; paint chips were to be collected on plastic sheeting placed along the foundation. The painter tried wet scraping, but the paint became an unmanageable mess of wet paint chips that stuck to the plastic sheeting, which was difficult to gather into a single container. Dry scraping was easier, and the paint chip residues from the project were readily collected and managed. Photographs were taken, and we and the painter estimated that about one-half of the paint remained intact on the house. The dry paint chips were collected and weighed, and the total metal quantities were estimated for the house.

Surface wipes. We measured the amount of metals in the interior surface dust of house 2 before, during, and after the project was completed. Using the U.S. EPA protocol (*10*), we collected wipe samples on interior floors and exterior hard surfaces, either on a measured 1 ft^2 area, or if irregular, the measured area. Wipe samples were collected and stored in the labeled sample cups that are used for extraction. Extraction was performed by adding 40 mL of 1M trace-metal–grade nitric acid to containers and soaking overnight. The wipes were then shaken for 2 hr at low speed on an Eberbach reciprocal shaker (Eberbach Corporation, Ann Arbor, MI). The samples were filtered with Fisher P4 filter paper (Fisher Scientific) and the extractant was placed into vials. We analyzed the extractant using an ICP-AES (Spectro CIROS; Spectro Analytical Instruments, Fitchburg, MA) that was calibrated with NIST-certified standards. The final dilution for a 1 ft^2 wipe sample was

Table 1. Pb (µg/ft^2) after power sanding house 1, which was covered with old exterior paint containing ~130,000 µg Pb/g.

Location	17 June 1999	23 June 1999	8 July 1999	10 February 2000
Side entrance, walk outside basement	5,270	1,370	900	1,340
Front entrance porch, brick	27,600	2,790	970	79
Back, brick patio	7,360	2,440	3,280	730
Back, upper porch, plastic				127
Interior window sill, child's BR first floor	390	84	NA	< 3
Wood floor at child's BR door, first floor		200	130	< 3
Living room, first floor behind stereo	23,300	44	94	< 3
Bathroom floor by sink, first floor		320	190	< 3
Kitchen floor (middle), first floor		580	230	< 3
Brown shelving with toys, basement	1,770	230	550	< 3
Ping-pong table, top surface, basement	390		120	17

Abbreviations: BR, bedroom; NA, not available.

Table 2. Pb (µg/ft^2) in multiple consecutive samples collected 28 July 2000 after power sanding house 1 (which was covered with old exterior paint containing ~130,000 µg Pb/g) and in soil samples.

Location	Wipe 1	Wipe 2	Wipe 3	10 February 2000
Wipe samples				
Floor outside children's BR (HEPA vacuumed)	24	50	40	< 3
Varnished door frame of children's BR	190	270	130	< 3
Soil samples (mg/kg)				
Yard sample	360			
House side, drip line sample	3,900			
Near parking pad	3,000			
Street-side sample	1,200			

BR, bedroom.

1:40 or calculated according to the area wiped. Sample blanks (~5% of the samples) or at least one blank for several samples were included with each run.

The wipe samples were collected during various work phases of the renovation project. Phase 1 wipe samples (B) were collected on 3 May 2000 before the project was begun. Phase 2 wipe samples (D1) were collected on 22 May 2000 during the most intense period of paint scraping, when the family was absent from the home and before interior cleanup was done. Phase 3 wipe samples (D2) were collected on 26 June 2000 when the family was back in the home; the interior had undergone intense cleanup and the exterior painting was in progress. Phase 4 wipe samples (A1) were collected 26 July 2000 after the exterior painting was completed but the basement floor and steps were unfinished. Phase 5 wipe samples (A2) were collected 11 October 2000 after the entire project was completed. We used the Friedman two-way layout to evaluate differences in the wipe tests of the entire before-, during-, and after-work phases of the project; comparisons between specific phases of the project are based on the sign test for matched pairs (*11*).

Soil samples. We collected soil samples outside house 2 before, during, and after the project. Soils were collected in several locations on the property, with emphasis on locations near the sides of the house and areas where the children played. All samples were placed in labeled plastic bags and taken to the laboratory. For initial preparation, we laid the samples out on paper towels to air dry for 24 hr (*12,13*). The air-dried soil samples were sieved with a 2-mm USGS #10 stainless steel sieve (Fisher Scientific). The sieved samples were placed into labeled bags for storage. Extraction was carried out by weighing 4 g soil into labeled 50-mL centrifuge tubes. Ten percent of the samples were prepared as duplicates. Sample blanks (~5% of the samples) and in-house reference samples were included in the analytical runs. We added 20 mL 1M trace-metal–grade nitric acid to the centrifuge tubes; the samples were then shaken for 2 hr at room temperature on the low speed setting of the Eberbach reciprocal shaker. After shaking, the samples were centrifuged at $1,000 \times g$ for 10 min. The samples were then filtered (Fisher P4 filter paper) into labeled 20 mL scintillation vials. Finally, samples were diluted 1:10 for a dilution factor of 50. Samples were analyzed by ICP-AES.

From the data collected, we estimated the potential amount of Pb (and other metals) released into the local environment if the paint had been sanded to bare wood. We also appraised dust conditions from 14 sites in the house before, during, and after work phases to evaluate the effectiveness of the interim controls for managing the dust from the Pb-based paint renovation project.

Results

Weight of paint on the house. We weighed 41 kg paint that was scraped from house 2. About one-half of the paint was in deteriorated condition and was easily removed from the exterior of the house; the remaining paint was bound intact to the wood and remained on the house. Thus, the estimated total weight of paint on the house was 82 kg.

Quantity of metals in paint. Quantities of metals from paint samples collected from houses throughout New Orleans (Pb, Zn, Cd, Mn, Ni, Cu, Cr, Co, and V) are shown in Table 3. There is a broad range of each of the metals in the paint samples. The paint from the case study house contained ~90,000 µg Pb/g paint chips, or 3.7 kg Pb in a bag of paint chips weighing 41 kg. Only one-half of the paint was scraped off the house; thus, if the house had been sanded down to wood, about 7.4 kg Pb would have been released into the environment. In addition to Pb, sanding the case study house would have released as dust 3.5 kg Zn, 9.7 g Cd, 14.8 g Cu, 8.8 g Mn, 1.5 g Ni, 5.4 g Co, 2.4 g Cr, and 0.3 g V. Although we emphasize Pb in this study, other potentially toxic metals are also associated with paint.

Environmental samples from the case study house. Table 4 shows the quantities of Pb in the interior dust and exterior soils before, during, and after the house paint renovation was completed. The overall results and the pair-wise work phase comparisons for 14 interior sites of the house are shown in Table 5. The Friedman two-way layout test showed that there was a statistically significant difference ($p = 0.000036$) in the quantity of Pb in dust wipes before, during, and after the work phases of the project (*11*).

There was either no difference or an improvement when the Pb dust conditions of the case study house (Table 5) before renovation were compared to those during and after the project was completed. The amount of dust after the major scraping, but before thorough cleaning, was not significantly different from the condition before the project was started. The thorough cleaning conducted after the major period of scraping resulted in the largest decrease of Pb dust, and the home had even less Pb than before the project began. The only significant increase occurred between work phases 3 and 4, although the amount of Pb dust during phase 4 was similar to the amount of Pb dust before the project was started. Overall, interior Pb dust remained about the same during the period of the project. The Pb dust for the basement floor and stairs remained consistently high until the areas were sealed with floor paint. Another indication of the relatively small amount of Pb dust in the house was the blood Pb results of the children. The older child exhibited no change in venous blood Pb: 4 µg Pb/dL before (May) and after the renovation (October). The younger child (the finger stick results) exhibited an increase from 4 to 12 µg Pb/dL; to minimize trauma, we did not attempt to confirm the data.

Soil in the center of the backyard of house 2 contained ≤ 79 µg Pb/g. Several years ago, fresh topsoil had been added to the backyard, and the Pb levels in these areas remain safe for children. A detailed examination of sites in the house showed some specific differences that required safety management, as discussed below.

Discussion

Pb poisoning in New Orleans is common, with about 25–30% of children < 6 years of age exhibiting blood lead levels of ≥ 10 µg/dL. Pb poisoning is directly linked to learning disabilities and behavioral and other health problems that begin during prenatal life and persist throughout life (*14,15*). Pb-based paint was marketed for house use from the late nineteenth century to its ban in 1978. The highest quantity of Pb in paint occurred before 1950, with peak use during the 1920s (*2,9*). Both the power-sanded house and the case study house were built during the peak use of Pb-based paint. Deteriorated paint and loose chips, although not desirable, existed on both houses (~5–10% on house 1 and ~50% on house 2)

Table 3. Metals (µg/g) present in paint samples from New Orleans houses (n = 31).

	Metal								
	Pb	Zn	Cd	Cu	Mn	Ni	Co	Cr	V
Minimum	112	52	7	5	24	4	13	2	2
10th percentile	416	1,343	9	8	31	8	22	3	3
25th percentile	5,045	15,365	14	11	44	11	39	5	3
Median	35,248	31,101	27	21	70	19	70	16	4
75th percentile	91,804	55,305	81	59	99	25	108	52	6
90th percentile	126,022	72,707	131	178	135	34	158	186	9
Maximum	256,797	98,056	439	667	309	114	214	417	15
Case study	90,547	43,145	118	180	107	18	66	29	4

The case study house is shown for comparison with paint samples from other houses.

before renovation and did not seem to be the condition that triggered Pb poisoning. The poisoning episode was triggered by the enormous amount of Pb dust that resulted from power sanding. The idea that dust is a major contributor to medically significant Pb exposure is not new (*16*). Extreme Pb poisoning is related to inappropriate renovation of Pb-based paints, as indicated by the literature and applied experience (*2,9*).

Environmental changes during the case study project. The case study demonstrates that scraping and collecting deteriorated paint from a house is relatively safe and does not significantly contribute Pb dust to either the interior or exterior of the house. Before, during, and after the project, there were significant changes in the overall Pb dust in the house, and there were some specific areas where Pb dust increased. Pb dust increases were detected on the front porch and in the entry area. However, once the areas were identified as a problem, the painter and the family took immediate measures to manage those areas. Clean cardboard was placed on the porch floor, and the family increased the frequency of wet mopping the entry area near the front door. Compared with the power sanding experience described for the background family, scraping as a means of painting preparation introduced relatively small amounts of Pb dust, and the dust that was formed was easily cleaned up. Levels of Pb on the basement floor and stairs remained consistently high and not in cleanable condition until these areas were sealed with floor paint. This experience was also noted for house 1 (Table 1, Table 2).

The case study family took a 2-week vacation, so they did not inhabit the house during the most intensive period of paint scraping. In addition, the family was conscientious about child care and in keeping their home clean. They paid careful attention to the details of the dust wipe results and worked out measures, such as removing shoes at the entrances, to prevent accidental tracking of paint chips and dust into the house. Other informed families, working closely with knowledgeable painting contractors should be able to duplicate the safer work and cleanup practices used in this project.

There are some potential problems with the method of disposal of the paint chips, although the paint contractor followed the standard procedure for household waste as provided by an official of the Louisiana Department of Environmental Quality. The paint chips (41 kg) were bagged and placed into the waste container and removed from the property as part of routine garbage pickup by City of New Orleans; they were presumably deposited into a landfill. The metals in the paint chips are relatively stable and probably do not leach into the water table as long as water pH is not acidic. If the paint chip wastes were to become acidified or to end up at a poorly designed and operated incinerator, they could become dispersed as a hazardous material into the environment. If the painters do not collect the scrapings, the paint debris would add to the accumulation of Pb and other metals in soils around the house.

Quantification of potential metal emissions. The case study house (house 2) provides information necessary to quantify the hazard associated with old paints. The total tolerable daily intake (TTDI) for children < 6 years of age is about 6 µg Pb daily from all sources (*17,18*). The TTDI is empirically derived by measuring excretion of Pb through urine, feces, sweat, hair, and nails; studies indicate that 6 µg/day is the maximum amount of Pb that can be excreted. This represents the maximum amount of Pb that can be ingested on a daily basis without an increase in body burden. Perspective on the impact of renovation can be estimated by comparing the TTDI of children with the amount of Pb that can be potentially released from a renovation project. In the case study, scraping yielded 41 kg paint chips. We and the painter both estimated that about one-half of the paint remained on the house. Thus, 82 kg paint containing ~90,000 µg/g Pb and other metals (Table 3) was present on the house. If the house had been sanded as first proposed, approximately 7.4 kg Pb would have been turned into dust, or over a billion (10^9) times more Pb than is tolerable to a child under 6 years of age. This

Table 4. Results of the case study house, which was covered with exterior paint containing ~90,000 µg Pb/g.

Samples	Work phase 1 (B) 3 May 2000	2 (D1) 22 May 2000	3 (D2) 22 Jun 2000	4 (A1) 26 Jul 2000	5 (A2) 11 Oct 2000
Wipe samples (µg/ft^2)[a]					
LR, front door entrance	12	187	7	15	9
LR, center of room	9	14	4	8	6
LR, window sill	38	24	5	86	28
LR floor, under window	22	53	8	7	4
Kitchen floor (middle)	9	71	1	7	6
Child's BR, next to window	8	29	21	5	5
Children BR, window sill	42	32	8	131	21
Master BR, next to AC	11	13	3	5	4
Closet, unsealed floor 1	15	18	13	17	7
Closet, unsealed floor 2	16	20	10	13	21
Guest BR, window well	2,800	682	40	317	321
Guest BR, window sill[b]	12	29	18	216	168
Guest BR floor, window[b]	10	23	9	19	14
Guest BR floor, 3 ft window[b]	9	6	5	13	7
Other wipe samples[c]					
Hall at basement stairs		475	4	8	2
Top stair to basement				318	22
Basement floor (middle)	259	231	145	141	38
Outdoor wipe samples (µg/ft^2)					
Front porch	35	1,200	224	29	11
Backyard, slab near AC	205	511	243	90	24
Fence treated, bare wood	29	23	9	10	8
Sandbox, wood ledge	35	7	7	13	8
Back of house siding			73	26	12
Soil samples (µg/g)					
4 ft from side of house	750	530	880	560	730
Backyard, next to house	330	500	240	120	220
Backyard, center of yard	15	30	79	15	22
Backyard, next to sandbox	115	60	37	150	59
Driveway play area		1,100	1,300	130	590
Sand box					< 4

Abbreviations: AC, air conditioner; BR, bedroom; LR, living room. Samples were collected during various work phases: before (B), during (D1 & D2), and after (A1 & A2) the scraping and painting project.
[a]Used for statistical evaluation. [b]No plastic on the windows. [c]Not included in the statistical evaluation.

Table 5. Results of the statistical tests for the case study house.

Matched pairs	*p*-Value	Trend
B vs. D1	0.1796	Similar
B vs. D2	0.0129	Decrease
B vs. A1	1.0000	No difference
B vs. A2	0.1796	Similar
D1 vs. D2	0.00012	Decrease
D1 vs. A1	0.1796	Similar
D1 vs. A2	0.1796	Similar
D2 vs. A1	0.0129	Increase
D2 vs. A2	0.0129	Decrease
A1 vs. A2	0.0386	Decrease

Based on surface Pb, the *p*-value (Friedman two-way layout test) for overall renovation process changes for 14 sites in the home and five phases of the project were 0.000036 (strong differences). Exact two-sided *p*-values for matched pairs before (B), during (D1 and D2), and after (A1 and A2) work phases of the scraping and painting project are based on the matched pairs sign test.

result illustrates the toxicologic hazard that sanding poses to pets and children. Sanding paint contributes many metals that can accumulate in the environment. In addition, because elemental Pb and the other metals do not decompose, they remain a permanent feature of the environment until they are removed or covered. Moreover, metals in dust, as described for wood trim and floors in the power sanded house (house 1) and demonstrated on the basement floor of the case study house (house 2), are often difficult to remove.

Other impacts of dust from sanding. Pb dust also poisons workers who sand the houses (*19,20*). Pb dust is easily transferred from workers' clothes to their home environments, and other members of their families may also be exposed. The dust blows in the wind and permeates the surrounding neighborhood, thereby transferring Pb to nearby homes and properties. Power sanding to remove paint is not neighbor friendly. In the case study project, no measurements were taken of the workers or of neighboring houses. As an adjunct aspect of the sanding, in addition to Pb there are other metals in old paints that are also toxic; the survey of exterior paint samples in New Orleans (Table 3) shows the quantities and ranges of metals that are present. For example, the current air standard for Cd is 10 $\mu g/m^3$ for inhalable dust and 2 $\mu g/m^3$ for the respirable fraction during an 8-hr time-weighted average (*21*); sanding the case study house would release 9.7 million µg Cd into air. This amount would place a worker sanding the house at risk to excessive Cd exposure. Likewise, 8.8 million µg Mn dust, 1.5 million µg Ni dust, and the other metals may contribute to exposure during a critical window of childhood that may contribute to chronic health problems later on in life (*15*).

Alternative renovation using coating products that minimize metal dust. Paint manufacturers recommend paint renovation methods similar to those used in the case study project; these include scraping loose paint (no dry sanding) and collecting and disposing of the paint chips in the trash (*30*). (As household wastes, the paint chips are exempt from laws governing hazardous waste.) As part of preparation for repainting, it is important to treat and destroy mildew, and it is essential to wash the entire surface with a solution of detergent to remove grease and grime (*22*). The surface must be rinsed thoroughly and allowed to dry before applying a primer coat to bare wood areas. The 100% acrylic paint formulations currently in use have reported a 20-year durability and are recommended for this method of preparation. An alternative to scraping, not tested here, includes new coating products that require little or no preparation at all. These coatings can be brushed or sprayed directly onto the unprepared surface to encapsulate old paint, dust, and chips, and they provide a tough, durable coating on interior and exterior surfaces. The development of encapsulating paints is progressing and now includes several products, Leadlock (*23*), Lead Block (*24*), and Child Guard (*25*), that are currently available. This growing list of products hold promise for managing and eliminating metal dust release during paint renovation of old homes.

Pb-based paint and leaded gasoline as sources of environmental contamination. The case study house is in a neighborhood were the median soil Pb is mapped at approximately 400–500 µg/g (*8,13*). Before the paint scraping project began, the soils near the house contained 500–900 µg Pb/g (Table 4). Pb loading of the urban environment is controlled by factors such as city size, inner-city location, traffic flow, and congestion during the five decades of use of Pb in gasoline (*26*). Pb loading continues because of the use of wheel weights that commonly detach and become ground into dust by the action of road traffic (*27*). About equal quantities of Pb, roughly 5 million metric tons each, was manufactured as leaded gasoline and Pb-based paint, or a total of 10 million metric tons of Pb, during the commercial use of these products; the history of these two products has been well researched (*2,28,29*). How do Pb-based paints compare with Pb gasoline as a community source of metal contamination?

The case study house (house 2) is located about 25 m from a busy city street. During the peak use of Pb in gasoline, the city street had traffic flows of around 10,000 cars/day. In the late 1960s and early 1970s, gasoline contained around 2 g Pb/gallon (0.53 g/L). At the peak use of leaded gasoline, 10,000 cars/day emitted at a rate of about 500 kg Pb/mile (310 kg Pb/km) of street per year (*13*). Thus, the traffic along a 0.1-mile (0.16 km) stretch of street in front of the case study house was releasing about 50 kg annually of an invisible cloud of Pb dust that dispersed on properties and in and around houses along the street. When the peak use of leaded gasoline occurred, the property along the street was being dusted with 50 kg/0.1 mile, or nearly 7 times more Pb per 0.1 mile annually than the potential one-time emission of ~7.4 kg of the case study house. It is possible that old paints contribute larger portions of other metals than vehicle traffic, although this topic requires further evaluation. The major difficulty is that there is a legacy of Pb and other metals from paint and automobile-related emissions that have accumulated in urban environments and now require management both indoors and outdoors to fully protect children from Pb exposure (*4*). Pb and other metal dust from power sanding old paint exacerbate the metal accumulation in the neighborhood beyond what has already taken place. The case study suggests that preventing interior and exterior accumulation of hazardous metal dust from old paint is an achievable goal.

Conclusions

Paint from old houses is hazardous, and power sanding poses a condition of severe risks, especially to children and pets. The scenario that occurred in New Orleans began with the failure to measure Pb content before renovation and then culminated with inappropriate preparation by power sanding. To improve the health and quality of life of children and workers living in cities with old houses, a basic step would be to require testing paint for Pb before beginning any painting project. To focus attention on the problem, all sanding should be prohibited by ordinance. In New Orleans, power sanding is already prohibited (to protect architecture) in the French Quarter, and this ban should be extended to all housing in New Orleans to protect children. A prominently advertised ban would assist with educating the public, painters, and contractors about the hazards of dust from sanding. Although Pb is traditionally the major consideration, other metals are also present in quantities that may present hazards. In this study we demonstrate that scraping accompanied by diligent cleanup is a safer method to prepare old houses for painting. Encapsulants, not described in detail here, are becoming available and may be desirable to prevent the release of dust. A positive benefit from using safer methods is that they contribute to primary prevention of exposure to Pb and other metals in old paint. These problems are not unique to New Orleans; all cities should prepare plans to manage the reservoir of accumulated metals in paint, dust, and soil to improve environmental conditions for families living in older houses.

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