

## Lead-Based Paint Residuals: Culprit or Cop-out?

ROD O'CONNOR<sup>1,\*</sup> and P. "BRENT" DUNCAN<sup>2</sup>

<sup>1</sup>Chemical Consulting Services, 1300 Angelina Court, College Station, TX 77840

<sup>2</sup>Department of Biology, Forensic Sciences, University of North Texas, P.O. Box 305220, Denton, TX 76203

**ABSTRACT:** Adverse health effects from ingestion and/or inhalation of lead-contaminated materials have been recognized for many years, and most frequently associated with lead-based paint in U.S. homes built prior to 1978. There is no question about the hazards of flaking paint or dusts accumulated from paint deterioration or improper paint removal methods. However, there is strong evidence that many lead exposures blamed on lead-based paint are, in fact, due primarily to other sources. This study demonstrates that large areas of heavily lead-contaminated soils cannot reasonably be attributed to lead-based house paint, and that it is possible to use chemical fingerprinting to eliminate paint as a major contributor to interior dust lead levels.

### INTRODUCTION

**S**INCE the early nineteenth century, lead-based paints were used in U.S. housing, with "white lead" [ $2\text{PbCO}_3 \cdot \text{Pb}(\text{OH})_2$ ] as the principal pigment [1], until paints with high levels of lead were banned in 1978 by the U.S. Congress [2]. Even today, many older homes have residual lead-based paints in deteriorated condition that pose a risk of ingestion and/or inhalation of lead [3,4]. Improper methods of removing old paint may increase exposure risks [5,6,7]. However, the "unique" association of lead poisoning with lead-based paint has become such an established myth that even governmental agencies have perpetuated it [8]. For example, the United States Environmental Protection Agency (USEPA) has made the statement that "Lead contaminated soil is a *lead-based paint hazard* under the Disclosure Rule if the lead is at sufficiently high levels, *regardless of the source of lead contamination.*" [9].

In 1924, a new source of widespread lead pollution in the U.S. began with the introduction of leaded gasoline [10]. In spite of numerous studies linking leaded gasoline with increased blood lead levels, especially in children near heavy vehicle traffic areas, the tetraethyl lead additive was not banned in the U.S. until the 1980s, and

not in the European Union until 2000. Accordingly, many studies began to associate lead health effects with exposures to both lead-based paint and leaded gasoline [e.g., 11–16].

Many lead compounds, including "white lead" and the residues from leaded gasoline vehicle exhausts, are soluble at pHs < 7, so that topsoils impacted by even slightly acidic rainfall should have dissipated the lead somewhat over the many years since these sources were significant. Even "pure" rainwater saturated with carbon dioxide has a pH below 6. Although paint from older homes may have continued to flake off over the years, and some leaded gasoline is still in limited use (e.g., in some light aircraft), these sources are unlikely to account for much lead in present day topsoils. Recent measurements of soil lead in heavily trafficked areas have shown concentrations averaging less than 150 mg/kg [11,15], and a simple mass balance analysis clearly demonstrates that flaking house paint containing lead cannot account for more than a small amount of present day soil lead.

### A MASS BALANCE ANALYSIS

The percentage lead in paints has decreased over the years and is now limited in the U.S. to 0.06%, by weight. Homes that were painted with lead-based paint many years ago will typically have been repainted several times. Therefore multiple coats of varying composition will result in average lead content well below that of the earliest paints. The U.S. government currently

\* Author to whom correspondence should be addressed.  
E-mail: docroc34@hotmail.com

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defines "lead paint" as any paint sample having an average lead content of 0.5% (5,000 mg/kg) or greater, and a "soil lead hazard" as any bare soil in a children's play area exceeding 400 mg/kg, or in the rest of the yard of at least 1,200 mg/kg [8].

If a typical small yard had an area of only 0.3 acre (ca. 1,200 m<sup>2</sup>), and the topsoil to a depth of six inches (ca. 0.15 m) had an average lead content of 1,200 mg/kg, how much lead-based paint would have had to flake off and remain mixed with the soil over the years to account for the soil lead content, assuming a soil density of approximately one ton per cubic yard (ca. 1,300 kg/m<sup>3</sup>)?

$$\begin{aligned} 5,000 \text{ mg (Pb)/kg (paint)} \times \text{paint mass} &= \\ 1,200 \text{ mg/kg (Pb)/kg (soil)} \times 0.3 \text{ acre(soil)} & \\ \times 4,840 \text{ yd}^2/\text{acre} \times 1/6 \text{ yd.} \times 1.0 \text{ ton/yd}^3 & \\ \text{paint mass} &= 58 \text{ tons (ca. 53,000 kg)} \end{aligned}$$

Since typical lead-based paints contained less than 10 pounds (4.5 kg) of residual solids per gallon, this would correspond to more than 11,000 gallons (ca. 42,000 L) of paint for a small house, all of which would have had to flake off and be mixed with the soil.

Clearly, even if the paint averaged ten or twenty times as much lead, there is no reasonable expectation that such an extremely large quantity of paint possibly could have flaked off, been mixed into the soil, and avoided dissipation by rain over the years.

## ALTERNATE SOURCES OF LEAD

Two sources of large amounts of lead often have been overlooked or minimized: natural occurring lead and "point source" lead (e.g., from industrial operations such as smelters). Fortunately, there are not many areas of high lead deposits in natural soils, although a few are significant, such as the "Missouri Lead Belt" [17]. Point sources, however, are widespread and may be the main sources of soil pollution in many areas. Pollution from improperly designed lead battery production and recycling operations, although relatively rare, has resulted in several cases of severe lead poisoning [18]. Other point sources, for example, include lead mining operations, coal-fired power plants, and galvanizing facilities [19]. Numerous studies have identified very high lead levels in soils near active or abandoned smelter sites [e.g., 20–27]. These are of special interest because so many of these sites have been unrecognized by governmental agencies and the public.

In 2001, William P. Eckel and his colleagues reported that they had located 639 U.S. lead smelter sites,

most of which were abandoned and only 186 of which (29%) were known to the U.S. government [28]. Many of these sites were within a few blocks of residential areas in which high soil lead levels were detected. If zinc and other smelter sites emitting lead were to be similarly identified, an even larger number of locations might be recognized as having soil lead content primarily from sources other than lead-based house paint.

It is well established that soil, as blowing dust or "track-in" residue, is a significant contributor to interior household dust [e.g., 29–32]. In fact, the oft-cited argument that higher lead levels in soil around the drip zone from roofs is evidence that flaking exterior paint is the major soil source of lead is equally consistent with the fact that airborne soil [33] accumulated on roofs washes off with rain or melting snow onto drip zones.

Mass balance analysis and evidence of significant point source possibilities cannot be overlooked in assessing probable sources of lead in heavily contaminated areas. A chemical fingerprint may then be able to establish the relative contributions of lead-based paint and alternate sources to interior house dusts.

## DATA INTERPRETATION

It is important to realize that samples collected from possibly contaminated sites can provide useful information, but with significant limitations, for example:

### Soils

Surface samples (typically taken at 0–3" depth) can indicate recent deposition of airborne contaminants and, by comparison with indoor samples, the contribution of track-in soil to indoor pollution. Track-in estimates are limited to comparison with soils from typical track-in areas (i.e., areas commonly walked through by persons routinely entering the home).

Surface samples generally do not provide useful information about long-past airborne deposition because of the dissipation of many contaminants by winds, by volatilization (including biological conversion of otherwise nonvolatile species to gases), through uptake by plants, or by dissolution in runoff or percolation water.

Comparison of surface samples with samples at varying depths can help estimate how surface soils have changed over time. However, soil depth comparisons can, at best, offer information limited to surface soil losses by percolation. For contamination that occurred long in the past, the additional losses by runoff, volatil-

ization, and plant uptake will not be indicated by soil depth comparisons.

Comparison with similar type soils from apparently uncontaminated areas (“background”) can help estimate the impact of contamination sources.

“Risk Assessment” based on soil sampling will, at the very least, significantly underestimate risk from long term exposures to contaminants deposited years ago. Such assessments may be useful in deciding about remediation needs, but they will be essentially meaningless in estimating anything more than minimal health risks from past long term exposures.

### **Attic Dusts**

Attic dust samples, under ideal conditions, can provide much better information than soil samples about long-term contamination by nonvolatile air pollutants. This is because the attic dust is not dissipated by water, wind, or volatilization to the extent typical of soils—although some substances such as arsenic may be volatilized by household bacteria or fungi.

Only attics having good access to outdoor air through occasionally opened windows or through properly oriented soffit vents will accumulate airborne contaminants. Therefore, individual buildings may vary considerably in attic dust composition depending upon the attic ventilation, and also upon other factors such as distance and direction from contaminant sources, shielding by trees or other buildings. Consequently, a maximum attic dust finding in a particular area probably better reflects historic contamination patterns than would any individual attic dust or area-wide attic dust averages. However, attic dust does become diluted by “clean” dust during times when uncontaminated air is entering the attic. Accordingly, even the highest dust concentration levels will be significantly less than maximum levels that occurred during contamination events.

In interpreting attic dust data, attention must be given to alternative sources of particular contaminants, and especially if the attic is a storage facility for items coming from different locations.

Attic dust is not usually applicable to “risk assessment” unless the specific household has frequent access to the attic. Accordingly, attic dust is rarely used in assessing remediation needs.

### **“Old” House Dusts**

The USEPA has recommended sampling of rarely

dusted locations (e.g., tops of ceiling fans or door sills, under furniture, etc.) as useful in assessing “past” contamination. Such samples may reflect both track-in and air-deposited contaminants over a period of months, depending upon the frequency and efficiency of house cleaning activities.

Rarely will such dust samples reflect contamination events several years ago. Thus, risk assessments are limited to cleanup needs or estimates based on the assumption (usually indefensible) that the patterns found will be typical of long term exposures. Risk assessments based on such data are disputable because the areas tested are typically inaccessible for direct contact.

Comparison of such samples with those of track-in soils can help estimate the relative contribution of track-in contaminants to airborne contaminants during the time frame in which the dusts were deposited.

### **Floor or Doormat Dusts**

Comparison of floor and doormat dusts with samples of track-in soils can help estimate the relative contribution of track-in contaminants to airborne contaminants during the time frame since the floor or mat was last cleaned.

Since floors and mats are typically cleaned more frequently than areas of “old” dusts, they are less likely to provide information about long-term exposures.

### **HVAC Dusts**

Dusts collected from HVAC filters, when coupled with information about when the filters were last installed, can provide useful estimates of the average composition of airborne dusts in the home during the time the filter was in place.

Under ideal circumstances, if the total dust on the filter, the filter installation date, the air flow rate, and the periods of HVAC activity are known, then HVAC dusts could theoretically provide information about the average indoor air composition during that time period. This complete set of information is rarely available.

It must be noted that HVAC dusts will consist of both new airborne dusts and resuspended previously deposited dusts. Published studies of dust resuspension can assist in estimating relative contributions.

### **Dust Loading**

The USEPA and other agencies often rely heavily on

“dust loading” data—the amount of a contaminant found on a measured area of floor space or other specified location (e.g., window sill). Such data are probably more representative of the frequency and efficiency of house cleaning than of any particular contamination pattern. However, such data may be useful if they show levels above those identified by appropriate agencies as screening levels or action levels.

Unless the total amount of dust AND its composition are known, health risk assessments are essentially meaningless.

### Summary

Results from soil and dust sampling provide, at best, a “snapshot” of contamination at the time the samples were collected. To the extent that analyses reveal concentrations of pollutants above recognized “hazard levels”, such data can be useful in assessing remediation needs.

It is essential to examine possibilities of alternative sources for any particular contaminants and to carefully estimate appropriate source apportionments in order to establish which, if any, sources are major contributors to contamination.

Except in the case of ongoing contamination reasonably constant over time, current sampling data will not adequately address health risks from past exposures, or from future exposures if they are likely to increase. For contamination resulting primarily from major polluting activities several years in the past, health risk assessments based on current contamination levels will vastly underestimate risk.

### A SPECIFIC EXAMPLE: BLACKWELL, OKLAHOMA

From 1916 until 1974, the town of Blackwell in north central Oklahoma was the site of a major zinc smelter which emitted contaminants, including arsenic and lead, into the community during its operation and during parts of its subsequent closure and cleanup [34].

Beginning in 2006, a study was initiated of area soils and house dusts in order to estimate the geographical distribution and magnitude of residual arsenic and lead, and in an attempt to determine the extent to which the lead contamination could be linked to old smelter activities. Since many of the homes in the area are quite old and have deteriorated lead-based paint, as illustrated in



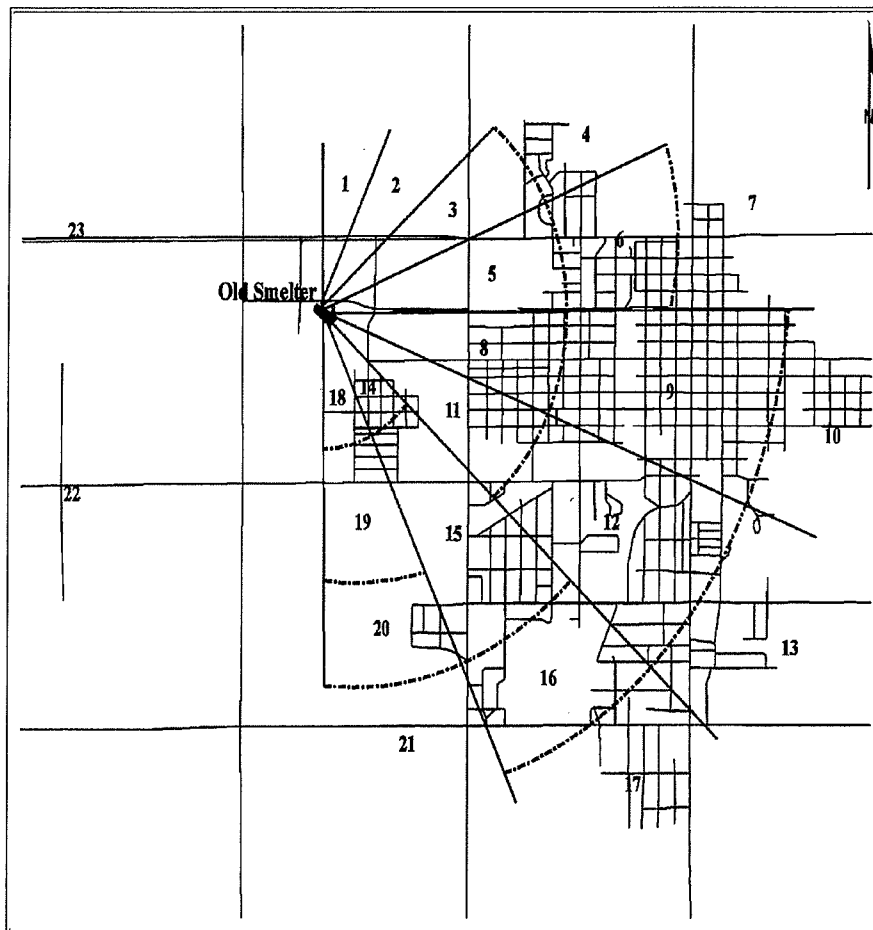
Figure 1. A typical 1920s Blackwell, OK home.

Figure 1, it was important to be able to distinguish among possible lead sources.

Blackwell has a population of approximately 7,700 and an area of approximately 5 square miles (13 km<sup>2</sup>). In order to obtain representative samples, the town was divided into sectors at varying distances and directions from the site of the old smelter, as shown in Figure 2.

### Materials and Methods

Sampling was performed by personnel of Aqua-Tech Laboratories, Inc., Bryan, Texas on three occasions: the week of December 3, 2006, the week of July 23, 2007, and the week of September 8, 2008. Sampling personnel wore hooded Ty-Vac suits, gloves, goggles, and dust masks. Suits and other gear were placed in trash bags after leaving each residence to avoid any possibility of cross-contamination. Paint samples were collected from areas believed to have the oldest paint at the home. Topsoil samples were collected from track-in and other areas at homes and, for background comparison, at sites located along roadways five miles from the old smelter. At selected locations soils were also sampled at depths of 0–3”, 0–6”, and 0–12”. House dusts were collected from attics, HVAC filters, measured floor areas, door mats, and rarely dusted locations such as the tops of ceiling fans or beneath large furniture, using Shark™ handheld vacuum cleaners (see [www.sharkvac.com](http://www.sharkvac.com)). These units are 1,000-watt vacuums with HEPA filter dust cups capable of trapping 99.97% of particles above 0.3 μm aerodynamic mean diameter. Separate vacuum cleaners were used at each location to avoid any possi-



**Figure 2.** Sampling sectors in Blackwell, OK. Distance from old smelter to farthest community sample was ca. 2 miles (3.2 km).

bility of cross-contamination. All sampling and sample preservation was done in conformity with USEPA Standard Operating Procedures, SOP #2012 for soils and SOP #2011 for house dusts.

Samples were prepared and digested according to Method SW846 3050B, then analyzed by ICP (inductively coupled plasma spectrometry) according to SW846 6010B [35]. All parameters followed standard protocol.

## Results and Discussion

Most of the homes sampled had lead levels in soils and/or dusts exceeding the recognized hazardous level of lead (150 mg/kg) [36]. Results are summarized in Table 1, with results above 150 mg/kg shown in boldface. Regarding ID numbers in this table, numbers beginning with 6 are from the 2006 sampling; those beginning with 7 are from the 2007 sampling; and those beginning with 8 are from the 2008 sampling. Values indicated by “less than” signs (<) are below laboratory reporting

limits, and “NA” entries indicate samples that were unavailable (e.g., no attic access) or not obtained (e.g., paint from newer homes).

Background samples were collected at locations along roadways at varying directions and at five mile distances from the old smelter site, as shown in Table 2. These data show that natural levels of lead in the area are well below the levels found in most Blackwell community topsoils, and that any lead remaining from vehicle traffic in the days of leaded gasoline is negligible.

As a “chemical fingerprint” to distinguish paint from other sources, lead/arsenic ratios were calculated for those fifteen homes (20% of those tested) having paint samples containing at least 5,000 mg/kg lead, and compared with lead/arsenic ratios for soils and dusts (Table 3). Additionally, the soil lead levels around homes built since 1978 show soil lead averaging above 150 mg/kg, and ranging as high as 856 mg/kg, further confirming sources other than lead-based paint residuals. Further comparisons with other soil and dust data (Table 4)

Table 1. Lead and Arsenic in Blackwell, OK (concentrations in mg/kg; decimal values rounded to nearest whole number).

ID No.	House Age	Sector	Max Soil			Paint			Attic Dust			HVAC Dust			Max House Dust			Floor Dust	
			As	Pb	Pb/As	As	Pb	Pb/As	As	Pb	Pb/As	As	Pb	Pb/As	As	Pb	Pb/As	mg/kg	µg/ft <sup>2</sup>
601	1950	4	15	446	30	1	478	478	6	327	54	<1	23	>23	8	64	8	37	2
801	1950	4	10	232	28	1	214	214	22	205	9	19	44	2	3	49	16	49	3
602	1954	5	9	255	28	1	23	23	17	261	15	1	43	43	4	78	20	34	29
701	1925	5	4	176	44	<2	2,510	>1,250	11	548	50	6	70	12	9	121	13	13	>1
802	1930	5	50	373	7	1	43	43	12	146	12	20	126	6	18	151	8	151	50
603	1920	6	15	329	22	3	2,200	733	22	394	18	9	160	18	9	192	21	192	17
604	1929	6	8	394	49	3	871	290	59	2,150	36	56	189	3	56	189	3	42	<1
702	1920	6	7	197	28	<2	6,800	>3,400	24	657	27	7	72	10	7	94	13	53	1
803	1930	6	5	290	58	6	22,100	3,680	7	775	111	16	95	6	16	95	6	50	1
804	1929	6	5	141	28	1	413	413	19	1,920	10	<86	<86	NA	2	1,890	940	123	2
605	1930	7	4	263	66	1	36	36	NA	NA	NA	3	32	10	11	41	4	7	<1
606	1920	8	21	252	12	5	8,150	1,630	141	1,650	12	<1	90	>90	8	310	39	56	5
703	1920	8	7	481	69	<2	36	>18	19	508	27	7	89	13	8	159	20	71	3
704	1980	8	12	865	72	NA	NA	NA	NA	NA	NA	19	127	7	19	127	7	41	1
705	1920	8	22	658	30	34	37,500	1,100	47	7,770	165	NA	NA	NA	7	136	19	61	6
607	1920	9	21	1,240	59	19	39,600	2,080	12	334	28	9	485	54	9	485	54	207	177
608	1948	9	6	176	29	2	355	178	4	92	23	10	95	10	12	170	14	80	11
609	1948	9	2	64	32	4	2,960	740	2	64	32	12	66	6	12	208	17	42	2
610	1920	9	11	361	33	NA	475	NA	3	98	33	11	75	7	15	98	7	83	1
706	1920	9	32	761	24	<2	5	>2	42	4,060	97	4	69	17	11	180	16	66	16
707	1920	9	22	2,650	120	<2	1,920	>960	40	447	11	11	343	31	9	636	71	636	54
708	1930	9	13	451	35	<2	5,240	>2,620	12	297	25	8	242	30	2	550	275	550	170
805	1958	9	4	217	54	1	589	589	13	216	17	6	61	10	7	608	87	45	11
806	1925	9	10	794	79	8	68,700	8,590	102	880	9	8	203	25	10	244	24	63	3
807	1920	9	16	1,090	68	5	10,800	2,160	NA	NA	NA	NA	NA	NA	14	415	30	319	37
611	1925	10	5	60	12	2	1,790	895	12	3,180	265	<2	37	>18	4	332	83	11	1
612	1920	10	4	138	34	1	126	126	1	106	106	<1	154	>154	5	185	37	142	2
709	1906	10	5	236	47	<2	482	>2741	17	548	32	NA	NA	NA	3	137	46	137	7
710	1920	10	4	2,330	582	<2	9	>4	9	211	23	NA	NA	NA	11	208	19	72	4
711	1907	10	5	175	35	<2	285	>142	<2	82	>41	NA	NA	NA	15	107	7	78	8
613	1920	11	9	228	25	5	184	37	100	1,360	14	5	134	27	7	136	19	82	5
712	1920	11	7	150	21	<2	16,100	>8,050	31	475	15	20	332	17	12	3,280	273	91	3
713	1920	11	10	240	24	<2	4,380	>2,190	82	1,350	16	7	34	5	10	118	12	65	4
808	1920	11	18	274	15	70	141,000	2,010	5	232	46	NA	NA	NA	6	301	50	165	247
809	1924	11	5	243	49	120	70,300	586	NA	NA	NA	12	76	6	12	76	6	63	4
614	1920	12	10	260	26	9	77,700	8,630	20	3,700	185	16	1,850	116	16	1,850	116	60	2
615	1968	12	8	57	7	1	307	307	20	368	18	7	38	5	7	161	23	90	21
714	1920	12	4	174	43	<2	50,500	>25,200	NA	NA	NA	15	129	9	16	157	10	49	9
810	1950	12	18	540	30	2	941	470	18	644	36	14	81	6	13	81	6	25	4

(continued)

Table 1 (continued). Lead and Arsenic in Blackwell, OK (concentrations in mg/kg; decimal values rounded to nearest whole number).

ID No.	House Age	Sector	Max Soil			Paint			Attic Dust			HVAC Dust			Max House Dust			Floor Dust	
			As	Pb	Pb/As	As	Pb	Pb/As	As	Pb	Pb/As	As	Pb	Pb/As	As	Pb	Pb/As	mg/kg	µg/ft <sup>2</sup>
811	1981	12	2	158	79	NA	NA	NA	NA	NA	NA	9	81	9	9	81	9	77	2
812	1920	12	2	212	106	<1	687	>687	NA	NA	NA	18	55	2	74	250	33	42	5
616	1945	13	8	114	14	45	72,700	1,620	5	1,480	16	103	6	16	499	31	499	5	
617	1925	13	7	371	53	1	8	8	16	10,200	638	4	59	15	6	79	13	45	12
618	1925	13	290	162	<1	21	10,900	519	3	122	41	7	84	12	7	84	12	49	3
619	1940	13	50	208	4	6	1,490	248	<2	171	>86	<3	249	>83	3	249	83	127	57
620	1964	13	6	56	9	3	6	2	7	230	33	11	45	4	13	45	3	37	3
621	1996	13	3	20	7	1	218	218	2	80	40	6	53	9	6	53	9	34	<1
715	1920	13	12	130	11	<2	20	>10	6	284	47	13	22	2	10	280	28	40	1
622	1950	14	6	38	6	2	2	1	32	473	15	<2	16	>8	17	170	10	74	8
623	1920	14	12	318	27	5	1,160	232	<4	174	>43	<4	127	>32	13	225	17	225	72
624	1998	14	15	28	2	NA	NA	NA	NA	NA	NA	2	29	15	7	51	7	51	1
716	1920	14	17	602	8	<2	2	>1	43	744	17	4	35	9	10	94	9	51	2
813	2000	14	5	43	9	NA	NA	NA	6	11	2	10	51	5	10	77	8	25	<1
625	1968	15	11	161	15	1	5	5	15	1,200	80	17	74	4	17	74	4	47	3
626	1930	15	5	46	9	5	3,220	644	32	495	15	3	42	14	11	63	6	64	30
627	1974	15	9	111	12	1	4	4	1	387	387	8	161	20	6	161	27	78	8
628	1981	15	7	255	36	NA	17	NA	4	57	14	<27	62	>2	10	217	22	105	15
629	1978	15	14	206	15	4	25	6	4	126	32	NA	NA	NA	1	43	43	29	2
630	1981	15	5	26	5	NA	NA	NA	4	36	9	<1	22	>22	3	51	17	51	2
717	1970	15	11	100	9	<2	857	>429	27	445	16	5	23	5	8	127	16	15	1
718	2004	15	45	499	11	NA	NA	NA	<2	110	>55	NA	NA	NA	3	40	13	40	<1
719	1982	15	10	94	9	<2	5	>2	<2	4	>2	NA	NA	NA	5	67	13	55	2
631	1962	16	7	108	15	2	79,600	39,800	6	365	61	NA	NA	NA	3	93	31	93	12
720	1970	16	2	13	7	<2	9	>4	11	151	14	NA	NA	NA	27	55	2	23	<1
632	1920	17	8	532	67	3	2,300	767	NA	NA	NA	NA	NA	NA	3	94	31	68	7
633	2002	17	5	61	12	NA	NA	NA	NA	NA	NA	27	40	1	61	64	1	59	10
634	1910	17	5	259	52	2	243	122	11	536	49	NA	NA	NA	4	6,920	1,730	59	576
721	1964	17	3	74	25	<2	1,460	>730	9	241	27	6	134	221	6	134	22	43	1
814	1940	17	4	257	64	1	43	43	16	512	32	7	65	9	3	160	53	46	1
815	1978	18	9	56	6	NA	NA	NA	NA	NA	NA	7	49	7	3	88	29	41	1
722	1975	19	4	62	16	<2	132	>61	7	73	10	4	30	8	6	38	6	27	2
723	1978	19	4	73	18	<2	470	>235	9	88	10	6	37	6	7	61	9	23	2
816	2000	21	5	27	5	NA	NA	NA	NA	NA	NA	17	43	3	7	51	7	19	<1
817	1920	23	18	93	5	NA	NA	NA	5	21	4	69	93	1	32	100	3	46	<1

**Table 2. Soil Background Five Miles from Old Smelter.**

Direction	Depth								
	0-3"			0-6"			0-12"		
	As	Pb	Pb/As	As	Pb	Pb/As	As	Pb	Pb/As
West	5.43	28.6	5.27	5.52	38.8	7.02	7.86	26.3	3.34
East	2.98	23.0	7.72	3.73	16.3	5.97	1.95	10.3	5.28
North	1.37	49.9	36.4	2.46	57.3	23.3	1.65	55.3	33.5
South	0.496	12.6	25.4	2.29	21.9	9.56	1.47	12.8	8.70
Northeast	3.67	14.1	3.84	4.90	12.6	2.57	4.03	10.8	2.67
Southeast	1.74	14.6	8.39	2.88	9.41	3.26	3.02	9.58	3.17
<b>Average</b>	<b>2.61</b>	<b>23.8</b>	<b>14.5</b>	<b>3.63</b>	<b>26.1</b>	<b>8.61</b>	<b>3.33</b>	<b>20.8</b>	<b>9.44</b>

**Table 3. Blackwell, OK Sampling Results for Homes with Paint Lead > 5,000mg/kg. (Concentrations in mg/kg; decimal values rounded to nearest whole number).**

ID No.	House Age	Sector	Max Soil			Paint			Attic Dust			HVAC Dust			Max House Dust		
			As	Pb	Pb/As	As	Pb	Pb/As	As	Pb	Pb/As	As	Pb	Pb/As	As	Pb	Pb/As
702	1920	6	7	197	28	< 2	6,800	> 3,400	24	657	27	7	72	10	7	94	13
803	1930	6	5	290	58	6	22,100	3,680	7	775	111	16	95	6	16	95	6
606	1920	8	21	252	12	5	8,150	1,630	141	1,650	12	< 1	90	> 90	8	310	39
705	1920	8	22	658	30	34	37,500	1,100	47	7,770	165	NA	NA	NA	7	136	19
607	1920	9	21	1,240	59	19	39,600	2,080	12	334	28	9	485	54	9	485	54
708	1930	9	13	451	25	< 2	5,240	> 2,620	12	297	25	8	242	30	2	550	275
806	1925	9	10	794	79	8	68,700	8,590	102	880	9	8	203	25	10	244	24
807	1920	9	16	1,090	68	5	10,800	2,160	NA	NA	NA	NA	NA	NA	14	415	30
712	1920	11	7	150	21	< 2	16,100	> 8,050	31	475	15	20	332	17	12	3,280	27
808	1920	11	18	274	15	70	141,000	2,010	5	232	46	NA	NA	NA	6	301	50
809	1924	11	5	243	49	120	70,300	586	NA	NA	NA	12	76	6	12	76	6
614	1920	12	10	260	26	9	77,700	8,630	20	3,700	185	16	1,850	116	16	1,850	116
714	1920	12	4	174	43	< 2	50,500	> 25,200	NA	NA	NA	15	129	9	16	157	10
616	1945	13	8	114	14	45	72,700	1,620	5	1,480	296	16	103	6	16	499	31
631	1962	16	7	108	15	2	79,600	39,800	6	365	61	NA	NA	NA	3	93	31
				<b>Average</b>	<b>37</b>		<b>Average</b>	<b>&gt; 7,410</b>		<b>Average</b>	<b>82</b>		<b>Average</b>	<b>34</b>		<b>Average</b>	<b>49</b>

**Table 4. Lead/Arsenic "Fingerprint" Comparisons (not including outliers, "less thans", or NAs).**

Sample Type	No. Samples	Avg. Pb/As
5-Mile Background Soil	18	11
All Homes Soils	71	31
Post-1978 Homes Soils	11	22
All Attic Dusts	56	50
All HVAC Dusts	51	14
All Max House Dusts	72	30
Lead Paint Homes Soils	15	37
Lead Paint Homes Attics	12	82
Lead Paint Homes HVACs	10	34
Lead Paint Homes Max Dusts	15	49
<b>Lead Paint Homes Paint</b>	<b>15</b>	<b>&gt; 7,410</b>

clearly demonstrate that, at least in the Blackwell community, lead-based paint is not a significant contributor to soil lead or to most interior house dusts.

### Source Apportionment

Having ruled out natural occurring soil lead, lead-based paint, and leaded gasoline residues as major contributors, it was important to consider other well-recognized sources [19,37]. The Blackwell community was not impacted by orchards or potato fields that might have used lead arsenate insecticide. There were no major golf courses using arsenical herbicides. There were no lead battery production or recycling operations. There were no galvanizing plants. A sample of “connie” material, the waste solids from the zinc smelter that was widely distributed in Blackwell as driveway or landfill material, was found to contain 1,340 mg/kg lead.

Accordingly, the only conclusion consistent with the facts is that the widespread lead contamination in Blackwell is primarily residuals from the old smelter operations., from operational emissions, blowing dusts, and distributed waste solids.

### CONCLUSIONS

This study clearly demonstrates that neither leaded gasoline residuals, nor the commonly blamed lead-based paint residuals, can possibly account for high levels of lead in large areas of soil. Additionally, the use of “chemical fingerprinting” can help to estimate the relative contribution of lead-based paint and other sources to interior house dusts. Although lead poisoning may sometimes result mainly from inhalation or ingestion of old paint, the widely-held belief that this is the chief source of lead poisoning must be reconsidered.

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