New Information on Lead in Dirt and Dust as Related to the Childhood Lead Problem

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It has been known for many years that the eating of leaded paint is the prime cause of lead poisoning and elevated blood leads of children living in deteriorated housing. Recently, there has been speculation that children may eat dirt and dust contaminated with lead exhausted from cars and that this amount of ingested lead is sufficient to contribute significantly to the childhood lead problem.

This paper reports on a twopart study conducted to evaluate the validity of the dirt-and-dust hypotheses.

The first part of the study was made to determine the source of lead in dirt to which children are normally exposed. Dirt samples were taken in old urban areas around 18 painted frame houses and 18 houses of brick construction. Samples also were taken around seven old frame farmhouses remote from traffic. Based on the fact that lead concentrations in the dirt were similar in city and rural yards at corresponding distances from the houses, it is clear that nearly all of the lead in dirt around these houses is due to paint from the houses. Lead antiknock additives are therefore not a significant contributor to the lead content of dirt around houses where children usually play.

The second part of the study used a naturally occurring radioactive tracer "Pb to determine the relative amounts of dust and other lead-containing materials (e.g., paint) eaten by young children. This tracer is present in very low concentrations in paint and in significantly higher concentrations in fallout dust. Stable lead and "Pb were analyzed in fecal material from eight children suspected of having elevated body burdens of lead and ten children living in good housing where lead poisoning is not a problem.

The normal children averaged 4 μg Pb/g dry feces, with a range of 2 to 7. Of the eight children suspected of having elevated lead body burdens, two had fecal lead values within the normal range. However, the remaining six were 4 to 400 times as high. Despite these differences in fecal lead between the two groups, the groups were essentially identified in the "Pb content of their feces. The "elevated" children averaged 0.040 pCi of "Pb dry feces, while the normal group averaged 0.044 pCi/g. The results provide sound evidence that these children suspected of elevated lead body burden were not ingesting dust or air-suspended particulate.

Lead poisoning in children, especially those under 4 years old, is prevalent in areas of our larger cities where housing has deteriorated. Historically, almost all cases of lead poisoning in children have been attributed to eating paint chips with a high lead content (1, 2). Recently, Fine et al. (3) in a study in Illinois, found that

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elevated blood lead was also common in smaller cities. In this study, they screened children from poor housing areas and concluded that the lead problem is not confined to large cities. The common factor between the large and small cities was deteriorated housing.

Recently, it has been speculated that dirt, dust, and air-suspended particulates may also contribute to lead poisoning in children (4). In order to consider these sources, it is necessary to define these terms. Air-suspended particulates are defined as solid particles in the air that can be removed by filtration. By dust we mean solid particles that settle from the air. Dust is usually measured by placing buckets or pans outside and allowing them to catch material that falls from the air. Equivalent terms used in this paper are dustfall and fallout dust. Dirt refers to dustfall mixed with other materials, including soil.

This paper considers two aspects of the childhood lead problem: (1) the major sources of lead in dirt around houses where children play; (2) the extent to which children take in dust and air-suspended particulates.

**Lead in Dirt**

Past studies have shown that deteriorating paint is an important source of elevated lead in dirt. Hardy et al. (5) have reported on analysis of lead in dirt near a barn remote from traffic in rural Lincoln, Massachusetts. Dirt next to the barn contained 2000 ppm of lead, and the level 20 ft from the barn was 160 ppm. Bertinuson and Clark (6) concluded that urban housing appears to be a larger contributor to elevated lead in dirt than emissions from vehicular exhaust. Fairey and Gray (7) found high concentrations of lead in dirt in yards, with the highest concentrations generally near the houses. They attributed this lead to paint and ashes.

In this study, we sampled dirt at nine sites around each of 18 frame houses in widely scattered urban areas of Detroit. These areas are characterized by old houses that had been painted with lead-based paint, presumably for many years. Analysis confirmed that all houses were coated with paint containing lead. Paint chips taken from the sides of the houses contained 3–26% lead. Most of the houses were vacant at the time of our sampling, but are in areas where the neighboring houses were occupied. Moreover, most of the vacant houses were in such a state that reoccupation is to be expected. Similarly, dirt samples were taken at nine sites around each of 18 houses of brick construction. In all cases, these houses have painted trim and were chosen so that the homes immediately adjacent were also brick to minimize contamination from the neighboring houses.

For each urban house, surface samples were taken at the following nine locations: (1) dirt in the street gutter; (2) dirt between the sidewalk and curb adjacent to the curb; (3) dirt two feet toward the house from the front sidewalk; (4)–(7) dirt on each of the four sides of the house within 2 ft of the house; (8), (9) dirt 10 ft from the house in the front and back yards.

We also sampled dirt around seven farmhouses in an area remote from traffic located about 30 miles from the nearest city and about 50 miles north of Detroit. All of these houses were on little-traveled gravel roads. Each house was set well back from the road, usually at least 150 ft. Samples were taken on all four sides of the farmhouses at 2, 10, and 20 ft from the houses. A sample was also taken on each farm several hundred feet away from the buildings and the road to allow a determination of the background level of lead. Samples were taken from the surface in the same manner as used for the urban samples.

Tables 1 and 2 show the data from this survey. Lead in dirt within 2 ft of the urban frame houses averaged 2010 ppm with no obvious bias for front, sides or back. Lead in dirt in the middle of the yards averaged 436 ppm, and again there was no bias toward front or back. The distribution around the brick houses was similar, but the lead
Table 1. Lead in dirt in Detroit.

| House type        | House | Front ppm | Back ppm | Sides ppm | 10 ft from house | Near sidewalk ppm | Curb ppm | Gutter ppm |
|-------------------|-------|-----------|----------|-----------|------------------|-------------------|----------|------------|
| Painted frame     | 1     | 1919      | 3001     | 1170      | 748              | 985               | 361      | 449        | 660        | 596        |
|                   | 2     | 4121      | 674      | 7284      | 6008             | 536               | 289      | 1301       | 432        | 1079       |
|                   | 3     | 4399      | 2103     | 1116      | 2548             | 278               | 608      | 326        | 610        | 508        |
|                   | 4     | 2377      | 2539     | 1117      | 925              | 216               | 131      | 1482       | 680        | n.d.       |
|                   | 5     | 920       | 2184     | 1211      | 1447             | 191               | 223      | 309        | 320        | 738        |
|                   | 6     | 126       | 233      | 186       | 916              | 58                | 157      | 343        | 321        | 1270       |
|                   | 7     | n.d.      | n.d.     | 1457      | n.d.             | n.d.              | n.d.     | 627        | 404        | 645        |
|                   | 8     | 3420      | n.d.     | 1380      | 5120             | 621               | 831      | 355        | 1957       | 1827       |
|                   | 9     | 179       | 372      | 611       | 1060             | 139               | 122      | 820        | 555        | 1047       |
|                   | 10    | 17590     | 4951     | 5552      | 7000             | 305               | 207      | 422        | 918        | 1387       |
|                   | 11    | 262       | 1585     | 5894      | 3402             | 197               | 219      | 506        | 338        | 1168       |
|                   | 12    | 285       | 292      | 140       | 104              | 170               | 149      | 152        | 220        | n.d.       |
|                   | 13    | 556       | 246      | 446       | 254              | 229               | 285      | 266        | 328        | 1046       |
|                   | 14    | 1256      | 655      | 1206      | 4248             | 208               | 149      | 1958       | 331        | 550        |
|                   | 15    | n.d.      | 162      | 1083      | 373              | 280               | 252      | 299        | 701        | n.d.       |
|                   | 16    | 1077      | 1660     | 1894      | 1460             | 708               | 1220     | 425        | 419        | 935        |
|                   | 17    | 768       | 1094     | 220       | 1483             | 952               | 614      | 227        | 708        | 1277       |
|                   | 18    | 4068      | 3535     | 1452      | 1278             | 1530              | 1410     | 1017       | 400        | 415        |
| **Average**       |       | 2349      | 1586     | 2257      | 1848             | 447               | 425      | 627        | 572        | 966        |
| Brick             | 19    | 380       | 222      | 106       | 146              | 77                | 72       | 246        | 301        | 564        |
|                   | 20    | 606       | 168      | 217       | 128              | 125               | 94       | 438        | 711        | 1670       |
|                   | 21    | 78        | 169      | 96        | 1540             | 103               | 48       | 1130       | 431        | 2085       |
|                   | 22    | 1030      | 701      | 838       | 725              | 148               | 188      | 485        | 881        | 1360       |
|                   | 23    | 352       | 344      | 883       | 486              | 203               | 480      | 416        | 966        | 3170       |
|                   | 24    | 687       | 197      | 91        | 222              | 219               | 97       | 263        | 303        | 656        |
|                   | 25    | 104       | 107      | 194       | 95               | 88                | 75       | 87         | 147        | 1070       |
|                   | 26    | 138       | 1915     | 474       | 1210             | 312               | 329      | 248        | 324        | 578        |
|                   | 27    | 382       | 835      | 597       | 4610             | 168               | 816      | 249        | 148        | 487        |
|                   | 28    | 377       | 283      | 1160      | 1500             | 228               | 163      | 403        | 2420       | 1410       |
|                   | 29    | 146       | 463      | 173       | 231              | 103               | 80       | 154        | 469        | 765        |
|                   | 30    | 146       | 203      | 102       | 269              | 108               | 84       | 169        | 330        | 600        |
|                   | 31    | 491       | 172      | 187       | 118              | 39                | 50       | 86         | 403        | 423        |
|                   | 32    | 140       | 72       | 1090      | 40               | 201               | 119      | 117        | 408        | 3140       |
|                   | 33    | 480       | 2350     | 800       | 652              | 816               | 417      | 301        | 395        | 867        |
|                   | 34    | 150       | 131      | 178       | 251              | 153               | 77       | 261        | 428        | 304        |
|                   | 35    | 366       | 442      | 218       | 281              | 111               | 244      | 317        | 750        | 2380       |
|                   | 36    | 227       | 243      | 276       | 2290             | 111               | 175      | 465        | 1210       | 298        |
| **Average**       |       | 351       | 501      | 426       | 595              | 156               | 200      | 324        | 612        | 1213       |

*a Many of samples for painted frame house contained readily visible paint chips, especially house 10; n. d. denotes not determined.

*b House next door was a painted frame house. This value not included in average.

levels were lower. The average concentration ranged from 351 to 595 ppm within 2 ft of the house and was 156 ppm in the front yard and 200 ppm in the back yard. As with the frame houses, there was no evidence of higher concentrations in the front yard compared to the back. Figure 1 is a graphical representation of the data.

The data for lead in dirt around the rural farmhouses (Table 2) are very similar to those for the urban frame houses (Table 1). The average lead concentration is 2529 ppm.
Table 2. Lead in dirt in rural area: painted frame farmhouse.

| House | 2 ft from house | 10 ft from house | 20 ft from house | Background |
|-------|----------------|-----------------|-----------------|------------|
| 1     | 2162           | 417             | 67              | 9          |
| 2     | 450            | 429             | 144             | 27         |
| 3     | 6338           | 2098            | 166             | 26         |
| 4     | 1886           | 129             | 74              | 74         |
| 5     | 5184           | 558             | 640             | 12         |
| 6     | 840            | 423             | 107             | 63         |
| 7     | 831            | 141             | 268             | 94         |
| Average | 2529        | 609             | 209             | 44         |

* Each value is the average of four samples, one collected on each side of the house.

ppm within 2 ft of the farmhouses and 609 ppm at 10 ft and 209 ppm at 20 ft from the houses.

Table 3 shows the comparison between frame houses in the city, brick houses in the city, rural houses, and one literature source of lead around a barn. The comparison indicates that most of the lead in dirt is due to paint, based on the following reasoning. The lead in dirt within 2 ft of the frame houses in the city averages just over 2000 ppm. The lead in dirt 10 ft from these houses averages over 400 ppm and is similar in the front and back yard. If vehicular traffic were a significant source of lead, the

![Figure 1. Lead in dirt around urban homes.](image)

Table 3. Summary of lead in dirt.

|                    | 2 ft from house | 10 ft from house |
|--------------------|----------------|------------------|
| Frame houses, city | 2010           | 436              |
| Brick houses, city | 468            | 178              |
| Frame houses, rural| 2529           | 609              |
| Barn*              | 2000           | 570              |

* From Hardy et al. (5).

front yard would contain more lead than the back. Since these data at 2 ft and 10 ft from the house are similar to our data from frame houses in rural areas and to the data of Hardy et al. (5), it is clear that traffic is not contributing significantly to lead in the dirt in the yards of the painted frame houses.

This conclusion is supported by the data on lead in dirt around the brick houses. The lead in dirt within 2 ft of these brick houses is more than double that at 10 ft, indicating that the painted trim of the house is the prime source. As expected, the much smaller painted surfaces of the brick houses result in much lower lead concentrations near these houses than near the painted frame houses. As with the painted frame houses, the concentrations 10 ft from the houses are similar in the front and back yards. Here again, it is evident that traffic does not have a significant effect. The lead in the street gutter was similar for both brick and frame houses. Thus, all evidence points to paint as the prime source of elevated lead in the yards, where the children would be most likely to play.
Children and Lead in Dust

The data from the first part of the study show that paint is the major source of lead in dirt around the houses where children usually play. The role of lead in air-suspended particles and in fallout dust must be considered separately, since lead in gasoline significantly contributes to lead contents of air-suspended particles and fallout dust (8).

To distinguish between the leaded paint a child might eat and the contribution of lead he might receive from eating dust, it is necessary to find a material that is present in dust but not in paint. The reverse would also be useful. Many elements in addition to lead are present in paint. These include titanium, zinc, calcium, barium, chromium, and aluminum, as well as traces of cobalt, manganese, and other metals. Unfortunately, these metals are also present in dust and dirt in relative amounts that are about the same as those in paint.

Lead-210, a naturally occurring radioactive isotope of lead, is a useful tracer for this purpose. It is generated from radon, which is present in the soil. Part of the radon escapes to the air and part stays in the soil. The radon disintegrates with a half-life of 3 days to produce $^{210}$Pb, which has a half-life of 22 yr (9). Because it is present in the atmosphere, fallout dust is enriched in $^{210}$Pb, while paint has very low concentrations of $^{210}$Pb.

We have analyzed samples of paint, dust, dirt, and air-suspended particulate for their $^{210}$Pb content. Table 4 shows the resulting ranges of the $^{210}$Pb content of these materials.

The large differences in concentration occur because of the vast difference in the amount of solids associated with the $^{210}$Pb, not because the $^{210}$Pb varies so greatly. For example, the amount of dust in the air per cubic meter is very small, and the amount of solids in a handful of dirt is enormous in comparison.

The concept was to use $^{210}$Pb as a tracer to determine the amount of dust and perhaps the amount of dirt eaten daily by a child.

| Material                  | $^{210}$Pb, pCi/g |
|---------------------------|-------------------|
| Paint chips               | 0.005-0.07        |
| Urban airborne particulate| 60-150            |
| Fallout dust              | 2-30              |
| Vacuum-cleaner sweepings  | 0.4-1             |
| Yard dirt                 | 0.3-2             |
| Street dirt               | 0.4-4             |

As lead and $^{210}$Pb are absorbed poorly in the gut, an estimate of the lead and lead-210 can be made from analyses of fecal matter. If a child has a high level of lead in his fecal matter and a normal level of $^{210}$Pb, we would conclude that the lead elevation is a result of eating paint. However, if both the lead and lead-210 are high in the fecal matter, we would conclude that dust and dirt are contributors in addition to paint.

At Children's Hospital of Michigan, we collected urine and fecal samples from children who were suspected of having elevated body burdens of lead. The evidence used was one or all of the following: (1) x-ray showed radiopaque materials in the gut; (2) history of pica; (3) elevated blood lead; (4) x-ray showed lead lines in the long bones. Fecal and urine samples were taken from eight such children. These children were 1 to 3 years old and all had exhibited pica tendencies. All stool and urine were separately collected during the first 24 hr after admission to the hospital to insure samples representative of the child's usual environment, not that of the hospital. To provide a baseline, combined stool and urine samples were taken from 10 children of the same age level (1-3 yr) who lived in good housing in Detroit and its suburbs where lead poisoning is not a problem. All samples were collected during the late spring and early summer months. These samples were analyzed for stable lead and $^{210}$Pb.

Table 5 shows the lead and $^{210}$Pb data for the normal children and the children with pica. The normal children average 4 $\mu$g Pb/g dry feces, with a range of 2 to 7. Of the eight children suspected of having elevated lead body burdens, two had fecal lead values (4 and 7 $\mu$g lead) within the normal range.
two tent the be feces was high in material children with feces, while the normal group and during treatment. If he had been doing so earlier. If he had been eating materials high in $\text{Pb}$, his tissue levels would have been elevated and $\text{Pb}$ would have increased in the urine along with the stable lead. This did not happen.

The $\text{Pb}$ data for these 18 children can be related to the amount of lead-210 that is present normally in the diet. The normal children in this study excreted an average of 0.67 pCi of $\text{Pb}$ per day in 15 g excreta (dry weight). This value agrees very well with an estimation based on $\text{Pb}$ data of Morse and Welford (10) for adults. They found that adults ingested about 1.4 pCi of $\text{Pb}$ per day. On the basis of literature estimates that a child consumes about half the food of an adult, (11, 12), an intake of 0.7 pCi of $\text{Pb}$ per day would be expected for a child.

### Study Techniques

#### Soil Samples

Soil samples were collected by taking the topmost layer of soil. All soil samples were dried at 100°C overnight. Lead was extracted with hot dilute nitric acid and determined by atomic absorption.

#### Biological Samples

The samples from the normal children were collected in acid-washed plastic containers for 24 hours by the mother according to the following instructions.
1. Collect all urine and feces for 24 hr and place in container provided.

2. If possible, child should use training chair. Samples are more easily handled in this manner than with diapers. A small amount of the (distilled) water provided should be used to wash out receiver. This water should be added to container provided.

3. If child is still in diapers, use disposable diapers. Place entire disposable portion in container provided. Keep the sample separated from any samples collected using training chair.

4. If child should have an accident and sample cannot be collected, the entire day's collection should be discarded and collection begun again the next day for 24 hr.

Urine and fecal samples from children admitted to Children's Hospital were collected separately in lead-free containers during the first 24 hr after admission.

All fecal and urine samples were weighed and dried at 100°C. The dry weight was recorded and the sample was taken into solution with nitric and perchloric acid. The lead was taken into methyl isobutyl ketone and analyzed by atomic absorption.

210Pb Analysis

Only a small portion of the methyl isobutyl ketone—lead solution was used to determine lead. The remainder was oxidized with nitric acid. After fuming three times with a few milliliters of HCl, the 210Pb was determined by the method of Black (19).

Summary

This report has described the results of a two-part study to determine whether lead emitted from motor vehicles contributes to the lead problem in small children. In the first part, we determined lead in dirt around houses in urban areas and rural areas. The data from the urban areas clearly show that the principal cause of elevated lead in the dirt in the yards is leaded paint on these houses. These data were confirmed by measurements of lead in dirt around farmhouses. The distribution was the same as that in the city, showing traffic was not an important consideration.

In the second part of the study, we determined the amount of air-suspended particulate or dustfall a child might eat. We used a naturally occurring tracer, 210Pb, which is present in relatively large amounts in dust but nearly absent from paint. The results showed that children with pica (and other evidence of high lead intake) and normal children excreted identical amounts of 210Pb. Consequently, dust and air-suspended particulate were not the sources of lead in these urban children.

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