0000005

Date: July 7, 1996

Review of Report by Robert Bornschein, April 1996, "The Effectiveness of Soil Removal on Lead Exposure in Granite City" [the 1994-95 Granite City Study]

By: Dr. Allan Marcus, United States Environmental Protection Agency, National Center for Environmental Assessment, Research Triangle Park

SUMMARY: I have reviewed the report by Robert Bornschein, April 1996, "The Effectiveness of Soil Removal on Lead Exposure in Granite City" [the 1994-95 Granite City Study]. Firstly, I find that this study is flawed in design, analysis, and interpretation. The design flaws include: (1) possible mismatch of seasons; (2) complete lack of longitudinal control groups; (3) inappropriate reference groups, also without repeated measurements; (4) absence of some essential measurements of dust, soil, and paint; and (5) inadequate number of houses to detect significant changes in floor dust, even if there had been appropriate control groups or baseline measurements. The analyses include no statistical tests, and in general the study is incapable of conclusive findings. The pathway model is an incomplete tabulation of simple correlation coefficients. U.S. EPA's preliminary assessments of the data show that almost all of the statistical assumptions that are required in order to derive valid causal interpretations from these data are, in reality, far from correct. Furthermore, the Study fails to report a substantial reduction in average floor dust lead loadings in three of the five remediated houses in the study for which pre- and post-remediation measurements are available. The Study also fails to report continuing reductions in both floor dust lead concentration and floor dust lead loading in all three residences abated before the study began. The author's interpretation that "study results also demonstrated that abatement of residential soil does not effectively reduce housedust levels and is likely to have a minimal effect on lead exposure" may in fact be contradicted by the data.

I also find that based upon U.S. EPA's review of the data provided in the report, and even given the limitations of the data, U.S. EPA's conclusions are quite different than Dr. Bornschein's conclusions. U.S. EPA concludes that 1) there is no evidence of recontamination, and 2) the effect of soil remediation has reduced childhood lead exposure through reduction in soil concentrations and reduction in dust lead loading.

First, U.S. EPA feels that there is no evidence of midyard soil recontamination. Upon examination of Table B-2 of the 1994-95 Granite City Study, 6 of the 38 yards sampled were not remediated by the U.S. EPA prior to the study. With the exception of 1443 Grand, the maximum soil lead concentration in the remaining 32 yards is 158 ppm (U.S. EPA resampling of 1443 Grand indicated lead levels of 29 ppm rather than 4257 ppm as shown on Table B-2).

Next, U.S. EPA has estimated the risk of elevated blood lead in houses for which repeated floor dust lead measurements were available, and finds that the average blood lead concentration expected for children living in remediated houses is lower in every case, due to the large reduction in soil lead. There is also a large reduction in the risk or likelihood of a child developing elevated blood lead from ingestion of contaminated soil and dust while residing in the remediated houses, although exposure to lead-based paint may be a problem in some cases. In other words, there is a very strong indication that the effect of soil abatement is beneficial rather than harmful. The U.S. EPA estimates of the risk of elevated blood lead suggest a reduction in estimated risk in the first year after remediation, in which long-term exposure to post-remediation levels would reduce the risk of elevated blood to much less than half of the pre-remediation risk. Similar analyses suggest further reductions in estimated risk in houses that were abated two years earlier. These calculations suggest that large reductions in soil exposure more than offset any transient and insignificant changes in house dust lead shortly after abatement, and that removal of the soil source may produce persistent reductions in the soil contribution to house dust. However, further actions may be considered to prevent recontamination from surrounding non-abated properties, from other sources in the community, and from lead-based paint inside and outside the residence.

1. DESIGN FLAWS IN THE 1994-95 GRANITE CITY STUDY

A basic tenet in the design of scientific studies is that the study design should eliminate or control alternative explanations of the outcomes, apart from those hypotheses being tested by the study. This was not achieved by the 1994-95 Granite City Study. The initial phase of the Study appears to have been put into the field in November, 1994, without sufficient time to sample dust lead levels in all of the houses that had been or were going to be remediated. The yard soil remediation had been intended for August, 1994, in order to have some effect on lead exposure during the expected summertime peak in blood lead concentration in children residing in these properties. It is well documented in other longitudinal lead exposure studies that childhood lead exposure tends to reach a peak late in the summer in the U.S. (U.S. EPA 1986, U.S. EPA 1995 for discussion of these points). November is well after this peak, and lead exposure pathways are more likely to reflect typical autumn-winter behavior patterns in households, such as reduced movement of exterior dust and soil into the house. Therefore, the 1995 follow-up measurements should have been made in the same seasonal period.

The first potential design flaw is the apparent lack of consideration of the seasonality in dust lead concentrations and loadings. "*Apparent lack of consideration*" is used, since no data is provided in the Granite City Study report (submitted to U.S. EPA for inclusion in the Administrative Record) about the dates of sample collection, potentially an important issue. The Granite City Study reports "findings through the fall of 1995" (p.3), but at least some field investigations such as the collection of street dust were made in August, 1995 (cited on p. 23 and on p. 6 of Appendix Table B-2 of the 1994-95 Granite City Study). Synchronous seasonal data matching the November, 1994 samples should have been collected in November 1995, rather than in August, 1995. In the absence of other information, it is possible that other samples of dust and soil were collected in August, 1995. It is therefore possible that the timing of the study produced a biased outcome, underestimating peak residential lead exposure in the pre-remediation data and maximizing estimated residential lead exposure if post-remediation data of interior or exterior dust were collected in August or September, 1995.

A second design flaw is the absence of any appropriate control group for the soil remediation study. In this case, because it is known that there are large average differences in soil lead and dust lead concentrations with increasing distance from the former NL/Taracorp lead smelter site, the appropriate controls would have been non-abated houses adjacent to or very close to the abated houses. It is well known that house dust lead concentrations and dust lead loadings can vary substantially from time to time even in the absence of abatement or intervention. There are many reasons for such variations, including sampling at different locations in the house, changes in weather and in household activity patterns, frequency and timing of house cleaning relative to dust sampling, and analytical uncertainty. Therefore, dust and soil lead concentrations and loadings could have increased in nearby non-abated houses. In the absence of any repeated house dust lead measurements in any non-abated houses, it is impossible to assign any meaning to the repeated measurements in the abated houses. Analysis strategies for residential lead abatement in the Urban Soil Lead Abatement Demonstration Projects are discussed by U.S. EPA (U.S. EPA, 1996). Choosing an appropriate control group or reference group is a key element in assessing changes in a longitudinal study. No repeated measurements were reported for the most appropriate control residences, so this appears to be a serious design flaw in the 1994-95 Granite City Study.

The third design flaw is that reference houses selected for the 1994-95 Granite City study are inappropriate because they are at least 0.25 miles from the abated houses. In view of the steep gradient for soil and dust lead with increasing distance from the former NL/Taracorp smelter site found in other studies (Illinois EPA, 1983; Marcus, 1995), this is already an inappropriate location, and there may be other important differences from the remediated housing. In fact, there is little discussion in the 1994-95 Granite City Study report about the selection of the reference houses. There is no indication that the reference houses are appropriately matched to the remediated houses. For example, even with similar lead paint loadings, there may be important differences between remediated houses and reference houses in terms of building condition or paint condition.

The fourth design flaw is the absence of information on paint condition, on area covered by lead paint, and on average or median paint lead loading. There is also an absence of information on midyard soil lead concentrations or soil lead in child play areas. Finally, although lead loadings and concentrations in window wells and on window sills have been identified as extremely useful indicators of external contamination of household dust (U.S. EPA, 1996), these were not measured in the 1994-95 Granite City Study.

A fifth design flaw is that the number of houses is too small to allow confident detection of changes, even relatively large changes in floor dust lead, because of the large intrinsic variation in house dust lead levels measured at different times. A key element in the design of scientific studies over the last thirty or forty years is the calculation of the "power" of the study to detect effects or differences of a specified magnitude in the face of intrinsic variability whose magnitude can be reasonably estimated. This is done in advance of the study as part of the study design, so as to know how large a sample size is needed in order to be able to detect differences of any size that may have practical significance. Such considerations are not reported in the 1994-95 Granite City Study. The author notes on p. 19 of the Study report that "data are available for only a limited number of dwellings, making it not possible to conduct a conclusive statistical analysis of this issue". Carrying out the Study in spite of a nonconclusive sample size is a design flaw.

2. FLAWS IN DATA ANALYSIS IN THE 1994-95 GRANITE CITY STUDY

The author of the 1994-95 Granite City Study uses Table 5-4 as the primary information driving his conclusions. Table 1 in this memo shows the five houses from Table 5-4 of the 1994-95 Granite City Study, the only residences with pre- and post-remediation floor dust measurements. The differences in floor dust lead concentration decreased in two houses between Nov. 1994 and some time in Aug.-Nov. 1995, and increased in three houses. The average was a decrease of 25 ppm. It is not certain whether the increases reflected recontamination, a seasonal increase between November and August, or a general increase in dust affecting the neighborhood that might have been detected in adjacent control houses if any had been sampled.

However, changes in floor dust lead loadings present a different story. Floor dust lead loading is the amount of lead per area of floor (i.e., milligrams of lead per square meter of floor area). Table 1 shows that floor dust lead loading decreased in three of the five houses, with a striking decrease from 4680 ug/m2 to 187 ug/m2 at 1431 Grand, and an overall average decrease of 813 ug/m2 in all five houses. Post-remediation dust lead loadings were all less than 200 ug/m2 except at 1412 Grand. Since dust lead loading was a better predictor of child blood lead than was floor dust lead concentration in the 1991 Madison County Lead Study, accounting for over 20 percent of the variance in the logarithm of blood lead (Marcus, 1995), it would be more accurate to say that the effect of soil remediation was more than a moderate reduction in childhood lead exposure in the first year after remediation, even in the absence of a statistically conclusive sample size, in the absence of any control or reference group, and in the absence of any additional measures to prevent recontamination.

TABLE 1

SUMMARY OF DUST LEAD CHANGES BEFORE/AFTER REMEDIATION, 1994-1995

Num.	Street	Remediation	Floor Pb Conc -94	Floor Pb Conc -95	Floor Pb Load -94	Floor Pb Load -95
1412	Grand	R	608	652	43	1728
1415	Grand	R	1070	303	1160	35
1418	Grand	R	109	522	328	128
1424	Grand	R	462	782	56	123
1431	Grand	R	1094	959	4680	187
Mean Decrease			25		813	

Notes: Remediation codes: R = prior to remediation, Nov. 1994

TABLE 2

SUMMARY OF DUST LEAD CHANGES IN REMEDIATED HOUSES, 1994-1995

Num.	Street	Remediation	Floor Pb Conc -94	Floor Pb Conc -95	Floor Pb Load -94	Floor Pb Load -95

1410	Grand	PR	480	216	768	181
1443	Grand	PR	1462	448	640	53
1406	State	AR	377	319	108	48
Mean Decrease			445		411	

Notes: Remediation codes: PR = previously remediated (Nov. 1993); R = prior to remediation, Nov. 1994; AR= immediately after remediation, Nov. 1994;

There were also three houses in the study for which repeated samples of floor dust lead were obtained, but both samples were post-remediation. The results are shown in Table 2. Floor dust lead concentrations and floor dust lead loadings both decreased from Nov. 1994 to Aug. 1995, concentration by 445 ppm and loading by 411 ug/m2. Table 2 suggests that even in the absence of specific interior dust abatement measures, removing the large exterior source of soil lead contributes to a progressive lowering of dust lead levels over time. Of course, the same reservations apply to this conclusion in the absence of controls.

The only other "analyses" in the Granite City Study are those implicit in Figure 5-1 of the report. The correlation coefficients appear to be simple correlation coefficients of the lead concentrations as reported in Appendix Table B-2, although those involving exterior paint concentrations cannot be as simply constructed when duplicate paint samples are considered. This is not the kind of pathway model described by Bornschein et al. (1986), which is a simultaneous multiple regression model of the sort developed by U.S. EPA for the Madison County Lead Study (Marcus, 1995) and for the longitudinal soil lead studies in the Urban Soil Lead Abatement Demonstration Project (U.S. EPA 1996). The correlation coefficients in Figure 5-1 do not represent any pathway regression model. The Pearson correlation coefficients are probably inappropriate in this application, since the Pb concentrations do not have a normal distribution, but are highly skewed. In any case, these data represent a hodge-podge of different housing types remediated one and two years earlier, without adequate qualitative or quantitative information. There is only longitudinal data for eight houses shown in Tables 1 and 2. This is not adequate for inferring changes in pathways due to remediation.

3. ERRORS IN INTERPRETATION IN THE 1994-95 GRANITE CITY STUDY

The pathways from source to floor dust have not been established by the 1994-95 Granite City Study. Critical data on lead paint as a source were missing, such as condition of the paint and the amount of lead paint outside and inside the housing unit. The maximum XRF Pb loading may characterize only a tiny spot on the house, as does the paint chip sample. Lead paint chips might have been sought in the perimeter soil samples before they were sieved, but this was not reported. There is no direct physical evidence in the Granite City Study that justifies the Study's assertions about the role of lead-based paint in exposure.

U.S. EPA has repeatedly expressed its concerns about lead-based paint. The relative contribution of lead in paint and lead in soil were evaluated by U.S. EPA in a reanalysis if the IDPH/IEHR study by Kimbrough et al cited on p. 23 of the Granite City Study. The U.S. EPA reanalyses (Marcus 1995) decisively refuted the IDPH/IEHR assertions, using regression and structural equation models that were correctly calculated (unlike that claimed in the Granite City Study). Both lead in soil and lead in interior paint were important predictors of lead concentrations in house dust, with each accounting for about the same amount of variation in the logarithm of dust lead concentrations. Lead in midyard soil was, however, quantitatively a more important source of lead in house dust than was lead in paint in most of the houses within about 0.6-0.7 miles from the former NL/Taracorp smelter site. This is not to say that lead in paint is not an important concern, but rather to point out that there is very strong reason to believe that lead in soil is an even more important concern in most residences in these neighborhoods. In other words, remediation of lead paint without soil lead remediation may not address the more important source of lead in the dust in these houses. The data presented in the Granite City Study are not inconsistent with U.S. EPA's evaluation of relative risks from different lead sources.

The Granite City Study asserts that "Street dust lead ... may serve as an important interior dust contamination source... " (p. 17). This has not been established by any physical evidence, nor inferentially by a correctly calculated structural equation model.

The assertion on p. 18 that "... the site is a continuing source of lead exposure for Granite City residents" is without foundation. The 1994-95 Granite City Study concludes, as did U.S. EPA (Marcus, 1995), that there is a significant source of lead exposure in Madison County that is inversely related to distance from the NL/Taracorp smelter site. U.S. EPA, however, eliminated all other sources except soil as being much less plausible or probable sources, based on generally accepted procedures of statistical inference. No other potential source or modifying factor showed the consistent relationship with distance that soil lead showed. Once soil lead was used as a predictor in a properly calculated structural equation model, there was no further dependence of house dust lead concentration on distance. Interior lead paint was also a predictor of house dust lead in addition to soil lead, but it showed a much weaker relationship to distance from the former NL/Taracorp smelter, and at any given distance there were houses with or without lead paint so that the effect of lead paint was not seriously confounded with soil or with distance. The relationship of street dust to distance from the smelter is as plausibly explained by soil and dust contamination of the street from adjacent properties and the adjacent unremediated easement strips as by continuing emission of fugitive dust from the waste pile at the site.

As U.S. EPA noted repeatedly, soil lead and house dust lead concentrations are much higher near the NL/Taracorp smelter site, and reflect historic deposition patterns from the former smelter activities (Illinois EPA, 1983; Marcus, 1995). Large reservoirs of historic lead dust deposits exist as exterior dust and surface soil in all of the unremediated residential yards and easement strips, and commercial and industrial properties in Madison County, reflecting a "point source" emission pattern that is higher closer to the former smelter. There is no way that the 1994-95 Granite City Study has been able to distinguish the source of these lead dusts and their potential for recontamination of remediated yards. Multi-element tracer methods might have been informative, but were not used. A plausible explanation of the relationship between street lead and distance is that street dust lead levels represent contamination from weathered yard soil and other sources related to former smelter activities. Since U.S. EPA was not permitted to remediate the majority of the easements and tree lawn areas next to the street, this is an obvious source of street dust lead. There may also have been a lower frequency of street cleaning in the neighborhoods being remediated than in other neighborhoods. In the absence of information on these points, we must reject the assertion on p. 23 that "Since streets are cleaned often (by either the city or by rain), the lead levels now observed cannot be the result of historic smelter operations." However, it may be useful to provide more frequent cleaning of adjacent streets until a substantial number of yards and other sources of exterior dust lead (easements, vacant lots, commercial properties) have been controlled.

The relationship of street dust to curb soil is informative, but there were no repeated measures of midyard soil that might have allowed estimation of the possible street source of soil recontamination in remediated yards. U.S. EPA feels that there is no evidence of midyard soil recontamination. Upon examination of Table B-2 of the Study, 6 of the 38 yards sampled were not remediated by the U.S. EPA prior to the study. With the exception of 1443 Grand, the maximum soil lead concentration in the remaining 32 yards is 158 ppm (U.S. EPA resampling of 1443 Grand indicated lead levels of 29 ppm rather than 4257 ppm indicated on Table B-2). Alternatively, using the 1991-1992 soil lead concentrations in the IDPH/IEHR study as a reasonable analogue of the 1995 Univ. Cincinnati midyard samples, perimeter soil recontamination is inconclusive. Even of the author of the 1994-95 Granite City Study himself notes on p. 17, "alternatively, these elevated levels may reflect the impact of contaminated rain water running off the roofs of these dwellings". Exterior dust lead and entry way mat lead concentrations do tend to indicate progressive contamination from exterior to the interior of the housing unit, although some critical mat lead data for 1994 from 1415 Grand and 1406 State are missing. However, mat dust does not characterize the only pathway from exterior to interior. Window lead would have provided useful information, but was not collected. Therefore, there are many gaps in the inferences that the Granite City Study tries to make.

The Granite City Study may be of some use as a pilot study evaluating the feasibility of pre- and post-remediation environmental assessment. Like any pilot study, one can learn from its mistakes. The study design has so many critical flaws that no scientifically credible conclusions could have been reached no matter how well the data were collected. Further evaluation of the data was informative, however. These are discussed in the next section.

4. PRELIMINARY ASSESSMENT OF DATA FROM 1995 GRANITE CITY STUDY

The data reported on 38 houses remediated in 1993 or 1994 appear to form the basis of the Granite City Path Model in Figure 5-1 of the 1994-95 Granite City Study. U.S. EPA has extensively used pathway models, both conceptually (U.S. EPA, 1986) and quantitatively (U.S. EPA, 1996) in assessing potential impacts of lead exposure. U.S. EPA therefore performed some additional assessments of these data to evaluate whether or not these data could be used in a quantitative pathway model for remediated housing, although in the absence of any longitudinal control group, such an analysis would have no relevance whatever to inferences about the effectiveness of soil remediation.

The first steps in any detailed examination of the data are simple visual inspections to assess the appropriateness of the data for certain kinds of analyses. In particular, the assessment of the association of two measured variables across a set of observational units is often reported by the use of the Pearson product-moment correlation coefficient ("correlation coefficient"), such as was done in the 1994-95 Granite City Study. It is well known that the correlation coefficient is a measure of linear statistical association, and that any of several patterns in paired measurements can render the correlation coefficient a rather misleading indicator, including (1) nonlinear patterns of relationship, (2) outliers or highly deviant and atypical measurements, and (3) clusters or subgroups of measurements whose within-cluster pattern differs from the between-cluster pattern (Tukey, 1977, and Mosteller and Tukey, 1978, give many examples). Virtually all of these problems occurred in the 1994-95 Granite City Study, rendering the use of the Pearson correlation coefficient inappropriate for quantitative analyses. The data are instructive, however, and reveal a number of possible problems in the data set that require resolution.

U.S. EPA analyses used floor dust lead concentration in the following figures, as the predictor of potential childhood exposure that was most often cited in the 1994-95 Granite City Study. The exterior contributions to interior floor dust could be best characterized by exterior entry dust lead and entry mat dust lead concentrations. Figures 1 and 2 show floor dust lead concentration plotted against exterior entry dust lead concentration. The plot symbols correspond to remediation status coded in Appendix Table B-1 of the 1994-95 Study, with A = AR for measurement immediately after 1994 remediation, P = PR for measurement in 1994 of property remediated in 1993, R = remediated after 1994 measurement, and Q = 1995 measurement. Figure 1 shows all of the data. It is clear that the least squares regression line (shown as a dashed line) that characterizes the Pearson correlation coefficient is almost completely determined by a single paired value corresponding to a very high exterior entry lead concentration of about 30,000 ppm, which is circled in Figure 1. Most of the data are much better fitted by the solid line in Figure 1. The solid line is derived from Figure 2, which shows the fitted least squares line without the circled data point in Figure 1. The straight line fit in Figure 2 is weak, but sensibly linear. Other studies have suggested that interior dust lead and entry dust lead are correlated both pre- and post-remediation (U.S. EPA, 1996).

Entry mat dust lead concentrations are also believed to be correlated with interior dust lead, but Figures 3 and 4 show virtually the same problem. The least squares regression line in Figure 3 is almost completely determined by the single high value with an entry mat lead concentration of about 20,000 ppm. When the circled point is set aside, then the solid line in Figure 3 (same as the dashed line in Figure 4) provides a very loose linear fit for most of the rest of the data.

The hypothetical importance of perimeter soil as a potential source of recontamination is mentioned several times in the 1994-1995 Granite City Study, but the results in Figures 5 and 6 suggest that this may be exaggerated. The fitted line in Figure 5 is unduly influenced by the outlying value at perimeter soil lead of 4000 ppm (circled), whereas most of the data are described by the positive solid line. As seen in Figure 6, even this relationship is very weak and virtually non-predictive. While some perimeter soil leads may be higher than desirable, it does not appear that elevated soil lead at the house perimeter is a source of immediate recontamination of interior house dust.

Midyard soil is shown in Figures 7 and 8. Unfortunately, no midyard soil samples for 1994 were reported in the 1994-95 Granite City Study, although the 1991-92 EPA soil samples may be relevant (a speculation which cannot be verified). Once again, a single outlying data value at about 4300 ppm seems to be responsible for the negative straight line in Figure 7. When the circled data point is set aside, then there appears to be no further relationship between interior dust lead and midyard soil lead in the remediated residences, as shown by the solid line. Figure 8 shows the data values without the outlying observation. The value marked "X" in Figure 8 shows that the outlying value would not be discordant if the midyard soil lead were 29 ppm instead of 4300 ppm; in fact, a subsequent sample suggested that 29 ppm is more nearly correct (OHM Corporation, 1996).

Figure 9 shows that there is very little relationship between curb soil lead concentration and interior house dust. Figure 10 shows a similar lack of relationship between house dust lead concentration and block-by-block street dust lead concentration. The assertions in the 1994-95 Granite City Study that street dust is a significant source of recontamination do not appear to be confirmed by these displays of data.

The role of outlying data points is also evident in assessing the role of lead-based paint. Even though there were only a few reported measurements of maximum interior XRF lead loading, Figures 11 and 12 show that there is a weak but positive relationship between interior dust lead and interior lead paint. The effect is not large, and is based on too few houses (N = 7) to have much quantitative significance. U.S. EPA is requesting assistance from HUD to protect the benefits of soil lead remediation by further stabilization or abatement of lead paint. However, the lack of information reported about interior lead paint in the 1994-95 Granite City Study leaves many unanswered questions. U.S. EPA has commented extensively on the possible role of deteriorating interior lead-based paint as an additional factor in childhood lead exposure in connection with soil remediation (U.S. EPA) and in particular in Madison County housing (Marcus, 1995). Additional comments would be superfluous, in view of the lack of information in the 1994-95 Granite City Study.

Figure 13 shows a similar relationship, with a very weak positive relationship between *exterior* maximum lead paint loading and interior house dust. The high loading at 40 mg/sq.cm may not be such an extreme outlier as to be excluded, since 2 of the 9 data pairs have XRF of about 20 mg/sq.cm. It would be particularly useful to have more information about the amount and distribution of exterior XRF on each house. The lack of relationship between interior house dust and exterior lead paint is better exhibited in Figures 14 and 15. Figure 14 shows the relationship between exterior lead paint concentration and interior house dust concentration. The relationship in Figure 14 is moderately negative and clearly influenced by the three circled data pairs, for lead paint concentrations of about 330,000 ppm (33%) and 100,000 ppm (10%). Figure 15 shows that, absent these three values, there is virtually no relationship between floor dust lead and exterior lead paint. In summary, exterior lead paint is not a likely candidate for recontamination of houses remediated one or two years earlier.

The visual evidence for recontamination of house dust by curb soil, street dust, or exterior paint is negligible. Quantitative assessment of lead pathways using these data is extremely difficult because of possible data outliers, at least one of which has been empirically confirmed as unreliable. While some remedies may exist, such as the use of logarithmic data transformation, or replacing Pearson correlation coefficients by "robust" correlation coefficients, it would be more appropriate to independently verify the measurements where feasible. Additional analyses of the data would require thoughtful and time-consuming exploration of alternative analysis methods.

5. THE RISK OF ELEVATED BLOOD LEAD IS REDUCED IN REMEDIATED HOUSES

The data presented in the Granite City study suggest at least a moderate reduction in childhood lead exposure in the remediated houses, based on the reduction in floor dust lead loading in three of five remediated housing units, and further reductions in lead loading in three previously remediated units. The interior floor dust concentrations increased in three of five remediated units, but the largest estimated increase in dust lead concentration was at 1418 Grand, from 109 ppm to 522 ppm. The actual dust lead exposure hazard may have decreased, since the dust lead loading at 1418 Grand went down from 328 to 128 ug/m2. However, another lead exposure hazard at 1418 Grand was greatly reduced, since the soil lead concentration was simultaneously reduced from 2065 to 490 ppm at the house perimeter and from 4840 to 85 ppm at the curb. Similarly, at 1424 Grand, dust lead concentration increased from 462 to 782 ppm, and dust lead loading increased from 56 to 123 ug/m2 which is rather low, while soil lead decreased from 2852 to 38 ppm at the perimeter and from 2869 to 64 ppm at the curb.

U.S. EPA systematically evaluated the potential risk to resident children in the following way. An estimate of the geometric mean blood lead in children was made using the Integrated Exposure, Uptake, and Biokinetic Model for Lead (denoted IEUBK) with pre- and post-remediation dust lead and soil lead concentrations. These concentrations were held constant, representing conditions for children who were exposed to pre-remediation levels for their lifetime, and those exposed to post-remediation levels for their lifetime. Children present during the remediation would fall between these two cases. The dust lead concentration used as input were those observed in 1994 and 1995 in the five houses in Table 1. The soil lead concentrations that are most appropriate for input in the IEUBK Model are neither perimeter nor curb soils, but whole-yard averages. Since it is not clear how these should be calculated from perimeter and curb soil samples, U.S. EPA used the midyard levels for postabatement levels, and the 1991-1992 levels in Table B-2 of the Granite City Study as pre-abatement levels, assuming that most children spend most of their time outdoors in their own yard away from house walls and away from the curb. Some additional sensitivity analyses are being carried out using different averages of perimeter, curb, and midyard soil. All other model parameters for intake and absorption were standard. Since measured dust lead was used, no assumptions about dust-soil ratios were needed.

The results in Table 3 show the difference in estimated geometric mean blood lead for children of ages 6 months to 6 years. While dust lead increased in three of five houses, soil lead decreased much more, and the net effect was a difference of 4 to 10 ug/dl lower mean blood lead in children who lived in remediated houses. Table 4 shows a similar comparison of the risk of blood lead of 10 ug/dl or greater. This is reduced by a large factor in every house, the smallest reduction being from 55 to 21 percent at 1431 Grand, the largest reduction from 76 to 5 percent at 1418 Grand. Sóme of these are still higher than desired, but in no case is there increased risk.

TABLE 3

ESTIMATED REDUCTIONS IN GEOMETRIC MEAN BLOOD LEAD BEFORE AND AFTER REMEDIATION FOR HOUSES REMEDIATED IN 1994

Num.	Street	Remediation	Floor Pb Conc -94	Floor Pb Conc -95	Soil Pb Conc -91	Mid-yard Soil Pb Conc -95	Mean Blood Pb Before	Mean Blood Pb After	Reduction in Mean Blood Lead
1412	Grand	R	608	652	1020	30	9.1	5.4	3.7
1415	Grand	R	1070	303	1640	30	13.0	3.5	9.5
1418	Grand	R	109	522	3450	35	14.8	4.7	10.1
1424	Grand	R	462	782	1520	23	10.2	6.1	4.1
1431	Grand	R	1094	959	1000 *	47	11.1*	7.0	4.1*

Notes: Remediation codes: PR = previously remediated (Nov. 1993); R = prior to remediation, Nov. 1994; AR= immediately after remediation, Nov. 1994; * = 1991 soil Pb not available, smallest possible value for which remediation would have been done.

TABLE 4

ESTIMATED REDUCTIONS IN RISK OF ELEVATED BLOOD LEAD BEFORE AND AFTER REMEDIATION FOR HOUSES REMEDIATED IN 1994

Num.	Street	Remediation	Floor Pb Conc -94	Floor Pb Conc -95	Soil Pb Conc -91	Mid-yard Soil Pb Conc - 95	Pct. Elevated Blood Pb Before	Pct. Elevated Blood Pb After	Reduction in Pct. Elevated Blood
1412	Grand	R	608	652	1020	30	40.4%	8.8%	31.6%
1415	Grand	R	1070	303	1640	30	66.9%	1.2%	65.7%
1418	Grand	R	109	522	3450	35	75.6%	5.3%	70.3%
1424	Grand	R	462	782	1520	23	50.1%	13.6%	36.5%
1431	Grand	R	1094	959	1000 *	47	55.5% *	21.1%	34.4% *

Notes: Remediation codes: PR = previously remediated (Nov. 1993); R = prior to remediation, Nov. 1994; AR= immediately after remediation, Nov. 1994; * = 1991 soil Pb not available, smallest possible value for which remediation would have been done.

TABLE 5

ESTIMATED REDUCTIONS IN GEOMETRIC MEAN BLOOD LEAD IN HOUSES PREVIOUSLY REMEDIATED

Num.	Street	Remediation	Floor Pb Conc -94	Floor Pb Conc -95	Soil Pb Conc - 94	Mid-yard Soil Pb Conc - 95	Mean Blood Pb - 94	Mean Blood Pb - 95	Reduction in Mean Blood Pb
1410	Grand	PR	480	216	[27]	27	4.5	3.0	1.5
1443	Grand	PR	1462	448	[29]	29*	9.3	4.3	5.0
1406	State	AR	377	319	[46]	46	4.0	3.7	0.3

Notes: Remediation codes: PR=previously remediated (Nov. 1993); R = prior to remediation, Nov. 1994; AR=immediately after remediation, Nov. 1994; * = Since measured value of 4257 was suspect, U.S. EPA resampled at 29 ppm (OHM Corporation, 1996)

TABLE 6

ESTIMATED REDUCTIONS IN RISK OF ELEVATED BLOOD LEAD IN HOUSES PREVIOUSLY REMEDIATED

Num.	Street	Remediation	Floor Pb Conc -94	Floor Pb Conc -95	Soil Pb Conc - 94	Mid-yard Soil Pb Conc - 95	Pct. Elevated Blood Pb -94	Pct. Elevated Blood Pb -95	Reduction in Pct. Elevated Blood Pb
1410	Grand	PR	480	216	[27]	27	4.2%	0.5%	3.7%
1443	Grand	PR	1462	448	[29]	29*	40.4%	3.5%	36.9%
1406	State	AR	377	319	[46]	46	2.4%	1.5%	0.9%

Notes: Remediation codes: PR = previously remediated (Nov. 1993); R = prior to remediation, Nov. 1994; AR= immediately after remediation, Nov. 1994; * = Since measured value of 4257 was suspect, resampled at 29 (OHM Corporation, 1996).

This probably represents a minimal effect, since dust lead continues to decrease in remediated houses. Similar calculations were carried out for 1410 Grand and 1443 Grand, and for 1406 State, as shown in Tables 5 and 6. Since these yards had been remediated even at the 1994 measurement, the 1991-1992 soil lead cannot be used, so we assumed the same midyard concentration for both 1994 and 1995. The measured midyard soil Pb concentration at 1443 Grand was 4257 ppm. This value was highly suspicious, exceeding the pre-abatement concentration measured by U.S. EPA (1970 ppm) as well as the 1995 perimeter and curb soil Pb concentrations. When the yard was resampled by EPA, the concentration was less than 29 ppm (OHM Corporation, 1996). Reductions in dust lead in all three houses correspond to further reductions in risk, ranging from small to large.

Therefore, on the whole, slight increases in dust lead concentration during the first year after remediation do not appear to pose any net increase in risk, in view of the decrease in soil lead. The data in Table 2 suggest that decreases in dust lead concentration may occur after the first year, as was noted in some components of the Boston Urban Soil Lead Abatement Demonstration Project (U.S. EPA, 1996). Of course, all of this must be put in context of comparisons with appropriate control housing units. There were too few remediated houses to allow statistically conclusive assessment, and no controls at all (which is clearly too few).

Children living in the remediated houses may still be at risk from other nonremediated sources, including lead-based paint inside and outside the house, nonremediated easements, and exposure to soil and dust lead at other houses that have not been remediated. Until exposure to all such sources are controlled, children with elevated blood lead may still be found in Granite City, although many fewer than would have occurred without remediation. The data presented in the Granite City Study, for all of their many inadequacies, do suggest a substantial reduction in risk of elevated blood lead associated with high levels of lead in soil.

COMMENTS ON APPENDIX C:

"U.S. EPA's Default Soil-to-Dust Transfer Coefficient of 70% is Not Valid"

The relevance of this Appendix to anything else in the 1994-95 Granite City Study is not obvious, but certain statements in the Study's Appendix C require clarification. The preliminary U.S. EPA evaluation found a strong relationship between dust lead and soil lead in data from the 1991 study carried out by the Illinois Department of Public Health (denoted IDPH) and the Institute for Evaluating Health Risks (denoted IEHR). This magnitude of the relationship was subsequently recalculated for the IEHR/IDPH data set using several different statistical methods. The analyses suggested that the relationship was distorted in the IEHR/IDPH study because of sampling and measurement protocols that differed from those used in other studies. For example, dust lead concentrations may have been inflated at higher values due to inclusion of paint chips in the combined sample, and due to the requirement that the amount of dust collected in the house should be 10 to 20 times larger in the IEHR/IDPH study than the amount typically collected in the Urban Soil Lead Abatement Demonstration Project studies (U.S. EPA, 1996) and in the 1994-95 Granite City Study. The soil lead data in the IEHR/IDPH study did not include house perimeter samples. Thus, while a strong relationship between soil lead and dust lead was identified qualitatively from data in the IEHR/IDPH study, this relationship may not be quantitatively translated into a relationship in which soil and dust samples are collected and analyzed differently, such as in the 1994-95 Granite City Study.

Estimates of the soil lead concentration contribution to house dust lead in the IEHR/IDPH study were somewhat less than 70 percent, depending on the statistical method used. This was taken into account in various risk assessments, using sensitivity analyses over a range of possible soil-dust ratios. Furthermore, the pre-abatement soil-dust relationship may not apply equally to all areas of Madison County, since the IEHR/IDPH data set provided to U.S. EPA did not include adequate location information to determine whether the residences were located in Granite City, Madison, or Venice Township. In view of these uncertainties, use of 70% as an upper bound value is not unjustified. Since the soil-dust ratio is believed to be somewhat site-specific, U.S. EPA's range of values based on the IEHR/IDPH Madison County data (albeit flawed data) seems more relevant than studies from Amherst, Massachusetts, half a continent away from Granite City, or studies from New Zealand, half way round the world from Granite City.

Finally, the last paragraph notes that interior dust lead concentrations may rise or may fall after the abatement of exterior soil. This is irrelevant to the use of soil-dust contribution fractions for risk assessment purposes, in which there is an assumption of a quasi-steady-state relationship between soil and dust. Even in studies in the Boston soil lead abatement project, some observed dust lead levels increased in a few remediated houses (U.S. EPA, 1996), but most blood leads decreased in children residing in these houses, due to the large and persistent decrease in soil lead. Sampling variability and observational fluctuations limit the use of dust lead as an indicator of abatement effectiveness. On average, decreases in soil lead were tracked by decreases in dust lead in remediated houses in the Boston Urban Soil Lead Abatement Demonstration Project (U.S. EPA, 1996). This is a more appropriate interpretation of the observations cited in Appendix C.

FIGURE 1. Floor dust vs Exterior Entry dust lead conc (all)

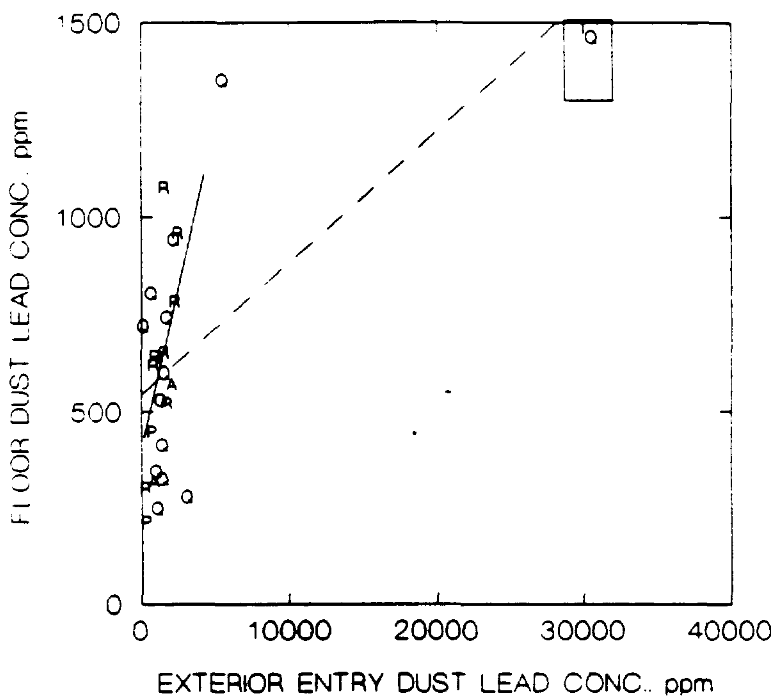


FIGURE 2. Floor dust vs Exterior Entry dust lead conc (low)

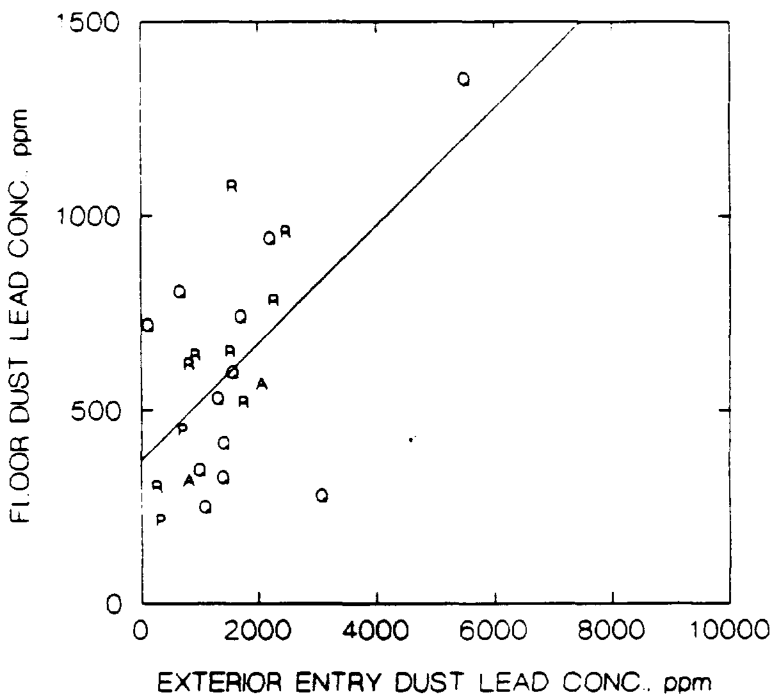


FIGURE 3 Floor dust vs Entry Mat dust lead conc. (all)

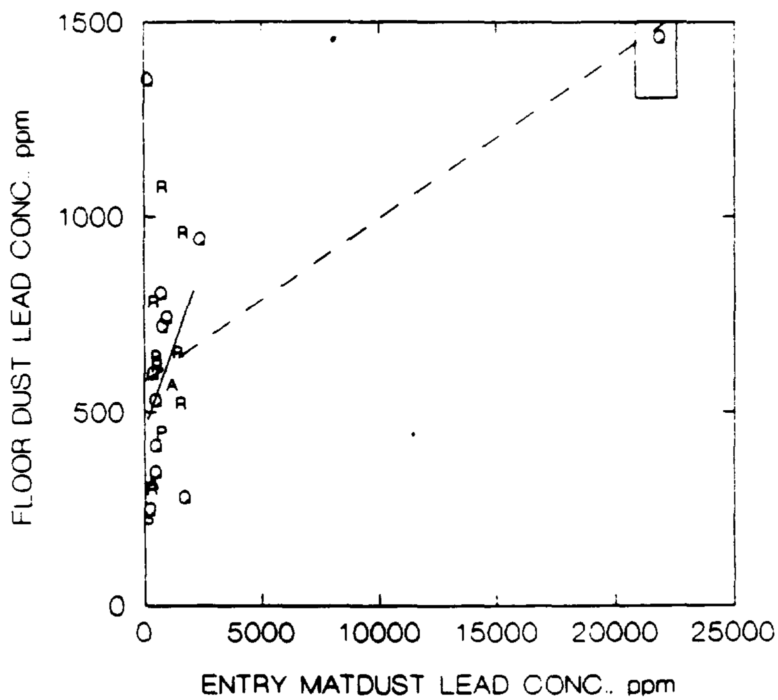


FIGURE 4 Floor dust vs Entry Mat dust lead conc. (low)

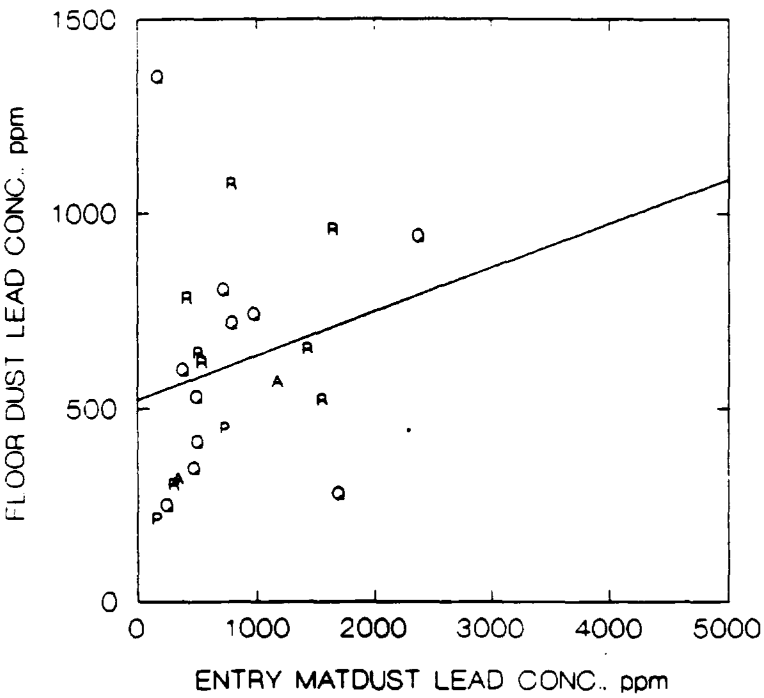


FIGURE 5 Floor dust vs Perimeter Soil lead conc. (all)

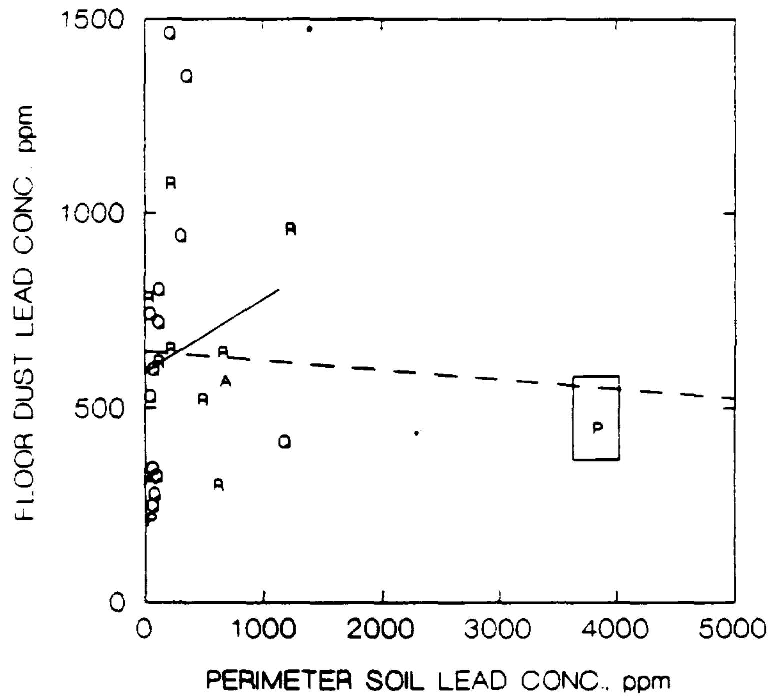


FIGURE 6. Floor dust vs Perimeter Soil lead conc. (low)

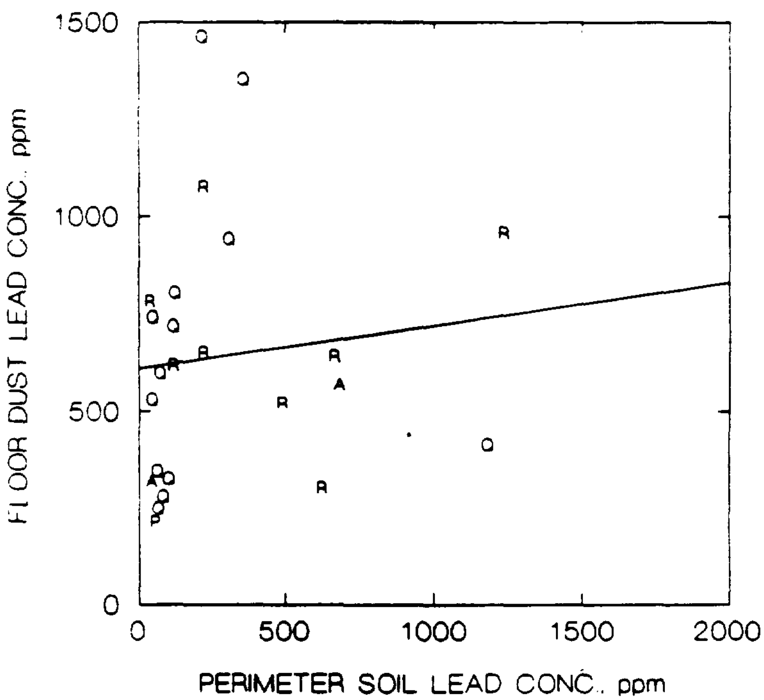


FIGURE 7 Floor dust vs Midyard Soil lead conc. (all)

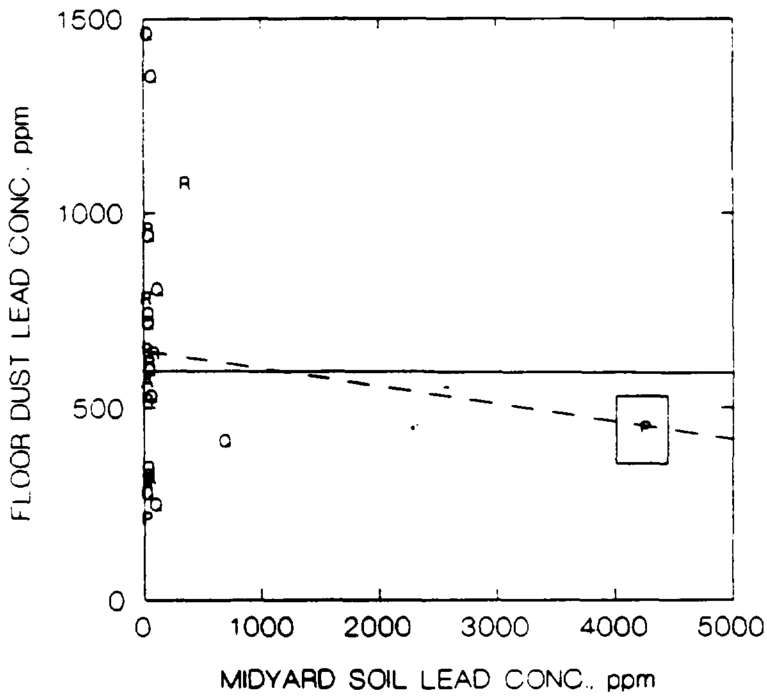


FIGURE 8. Floor dust vs Midyard Soil lead conc. (low)

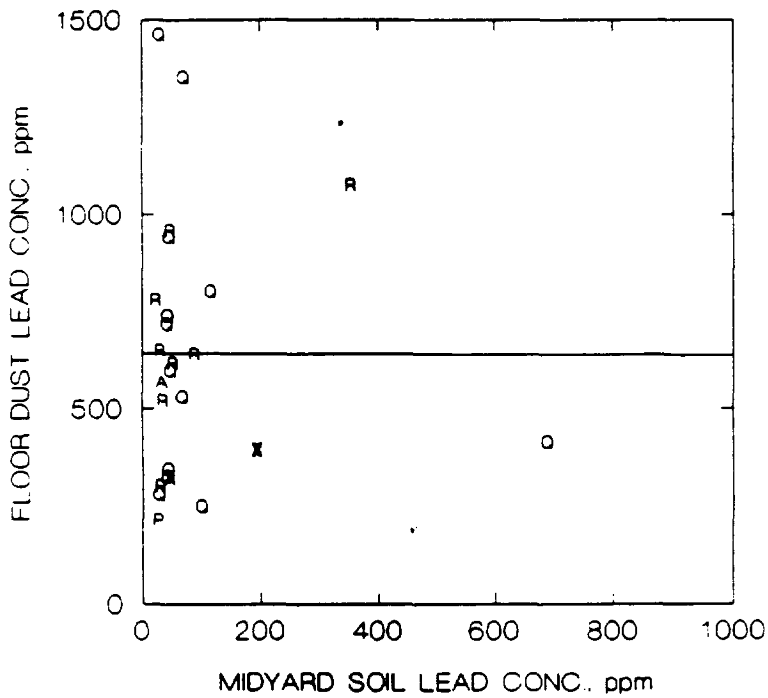


FIGURE 9 Floor dust vs Curb Soil lead conc. (all)

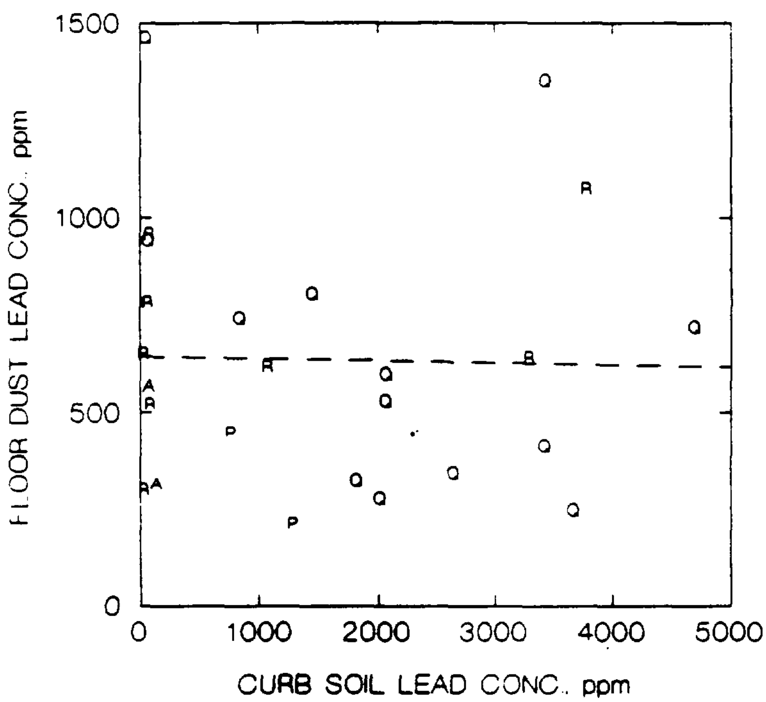


FIGURE 10. Floor dust vs Street dust lead conc. (all)

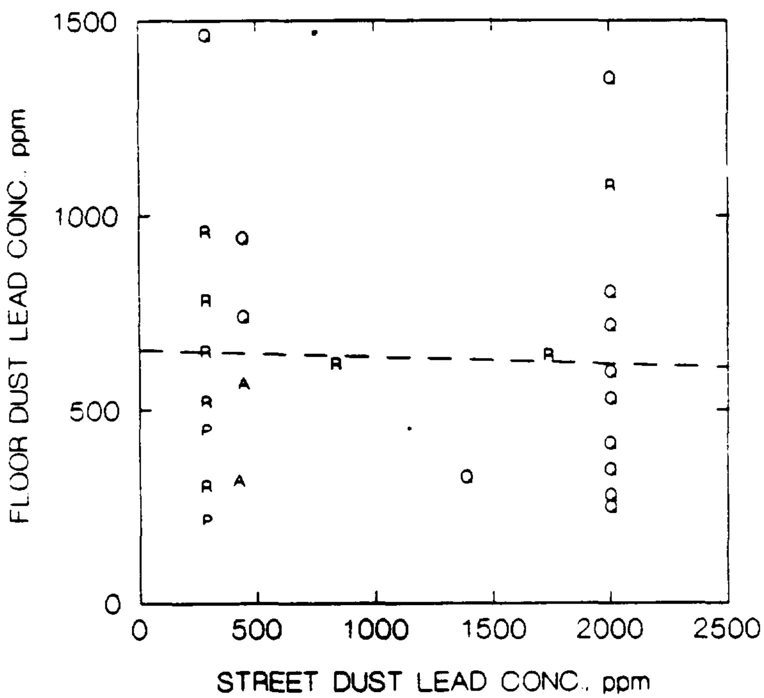


FIGURE 11. Floor dust vs Max. Interior Paint Pb Load (all)

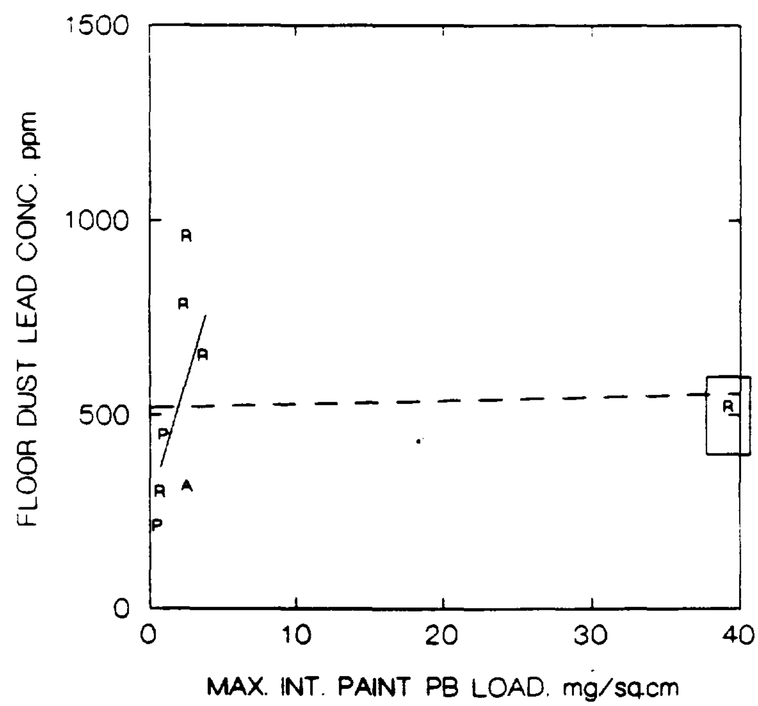


FIGURE 12. Floor dust vs Max. Interior Paint Pb Load (low)

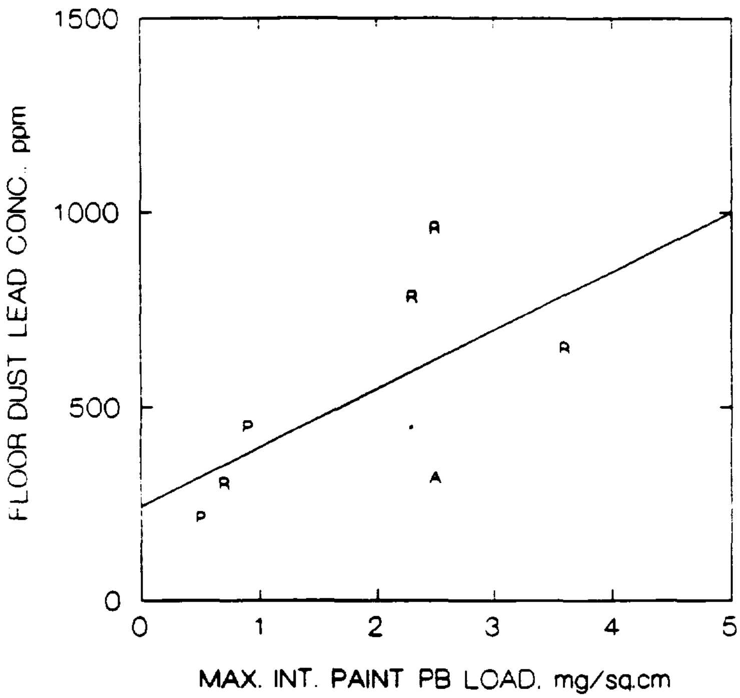


FIGURE 13. Floor dust vs Max. Exterior Paint Pb Load (all)

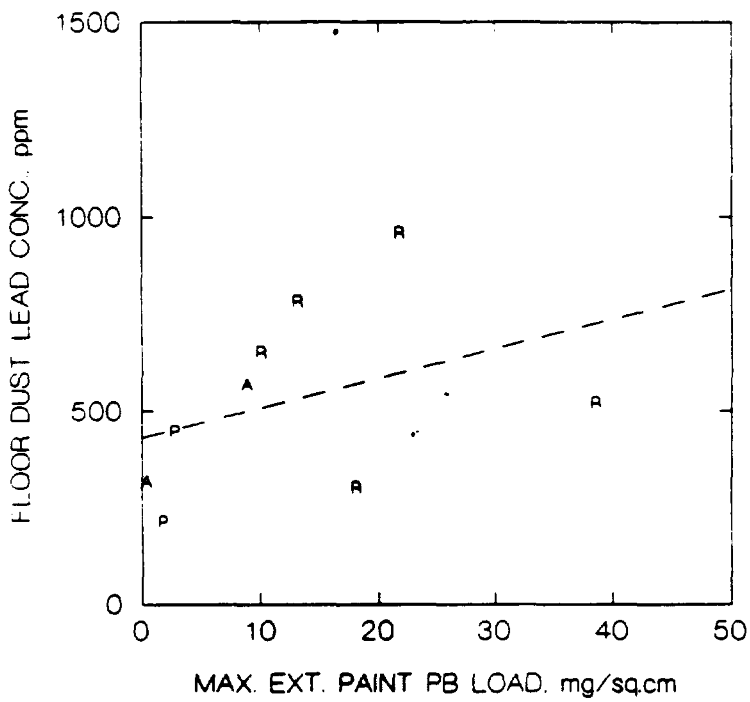


FIGURE 14. Floor dust vs Exterior Lead Paint Conc. (all)

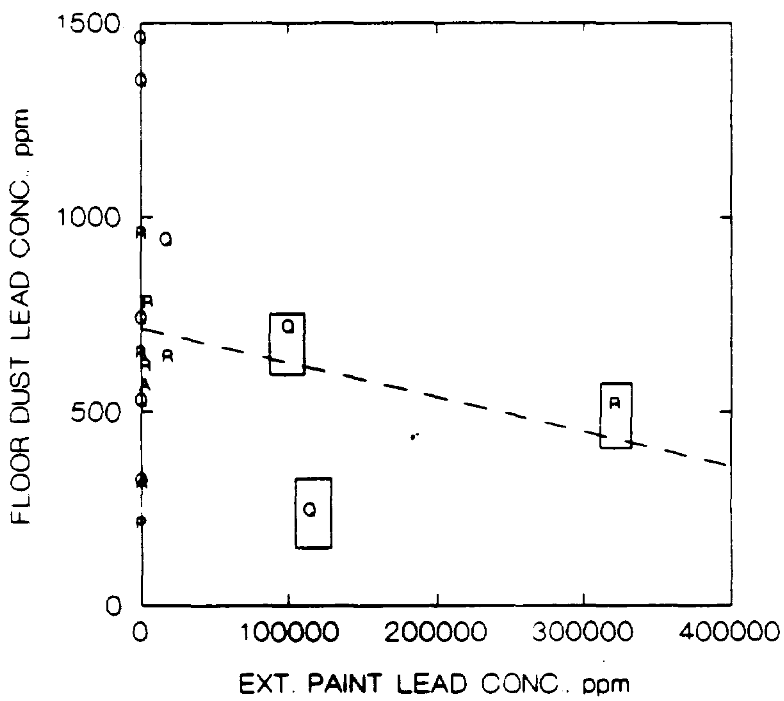
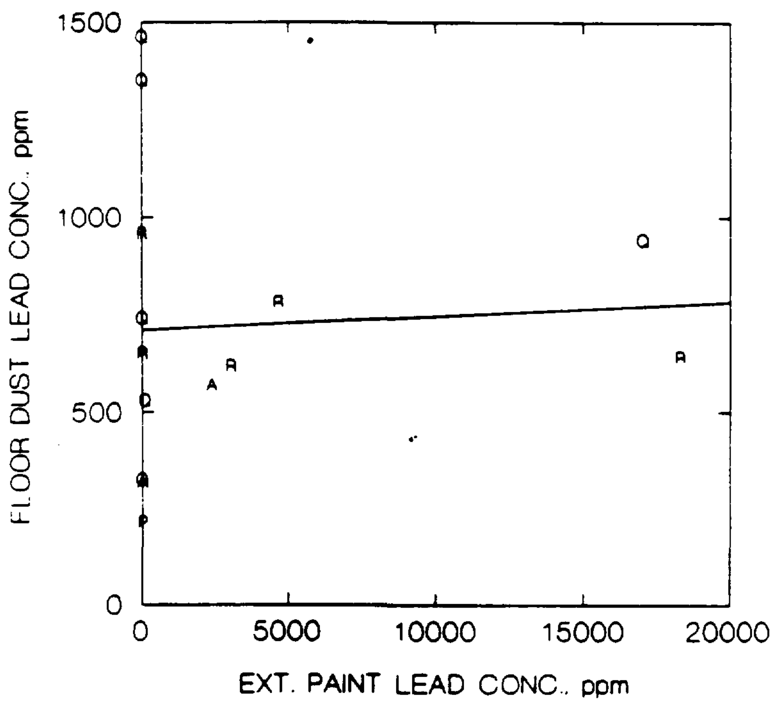


FIGURE 15. Floor dust vs Exterior Lead Paint Conc. (low)



REFERENCES

1. Bornschein et al., **Paper: Exterior Surface Dust Lead and Childhood Lead Exposure in an Urban Environment (Conference on Trace Metals in Environmental Health**, 1986 (Supplement to the Administrative Record Doc #71.)

2. Illinois EPA, April 1983, **Study of Lead Pollution in Granite City, Madison, and Venice Illinois.**, (Administrative Record Doc. #60).

3. Marcus 1995, **Statistical Analyses of Data From the Madison County Lead Study and Implications for Remediation of Lead-Contaminated Soil** (Supplement to the Administrative Record Index Doc. #377, Attachment 4).

4. Mosteller, F., Tukey, J., **Regression and Data Analysis**, Addison-Wesley, Reading MA, 1978.

5. Tukey, J. **Exploratory Data Analysis.** Addison-Wesley, Reading MA, 1977.

6. U.S. EPA 1986, **Air Quality Criteria for Lead**. (Administrative Record Doc. #69).

7. U.S. EPA, 1995, **Seasonal Rhythms of Blood-Lead Levels: Boston 1979- 1983, Technical Programs Branch, Chemical Management Division, Office of Prevention, Pesticides, and Toxic Substances Report, EPA 747-R-94-003, September 1995, Washington, DC.** (Second Supplement to the Administrative Record Doc. #7)

8. U.S. EPA, 1996, **Urban Soil Lead Abatement Demonstration Project Volume I: EPA Integrated Report, Office of Research and Development Report**, EPA 600/P-93/001aF, April 1996. (Second Supplement to the Administrative Record Doc. #8)

9. OHM Corporation, 1986, Memorandum Report, dated July 2, 1996, from Angela Sams, OHM Corporation, to Brad Bradley, U.S. EPA, regarding resampling of property at 1443 Grand, Granite City, Illinois (Second Supplement to the Administrative Record Doc. #6).

APPENDIX TABLE 1
SUMMARY OF DUST LEAD CHANGES, 1994-1995

Number	Street	Remediation	Code	Flr Conc -94	Flr Conc -95	Flr PbLd -94	Flr PbLd -95	Ext. Conc -94	Ext. Conc -95	Mat Conc -94	Mat Conc -95
1412	Grnd	R	9	608	652	43	1728	1076	1525	148	1430
1415	Grnd	R	9	1070	303	1160	35	190	276	-	304
1418	Grnd	R	9	109	522	328	128	3368	1747	115	1555
1424	Grnd	R	9	462	782	56	123	3253	2269	2355	414
1431	Grnd	R	9	1094	959	4680	187	1705	2479	283	1644
1410	Grnd	PR	8	480	216	768	181	218	327	439	167
1443	Grnd	PR	8	1462	448	640	53	1500	708	396	72
1413	Mad	AR	3	-	-	-	-	773	2170	-	6301

APPENDIX TABLE 1
SUMMARY OF DUST LEAD CHANGES, 1994-1995 (continued)

Number	Street	Remediation	Code	Flr Conc -94	Flr Conc -95	Flr PbLd -94	Flr PbLd -95	Ext. Conc -94	Ext. Conc -95	Mat Conc -94	Mat Conc -95
1406	State	AR	7	377	319	108	48	-	812	-	338
1413	Mad	AR	3	-	-	-	-	773	2170	-	6301
1415	Mad	AR	3	-	570	-	59	511	2058	-	1169
1429	Grnd	R	2	6385	-	944	-	2350	1988	1878	-
1436	Grnd	R	2	258	-	11K	-	753	1704	648	-
1438	Grnd	R	2	-	-	-	-	72K	19K	-	1480
1425	Mad	R	2	655	-	400	-	2424	804	877	-

APPENDIX TABLE 1
SUMMARY OF DUST LEAD CHANGES, 1994-1995 (continued)

Number	Street	Remediation	Code	Floor Conc -94	Flr Conc -95	Flr PbLd -94	Flr PbLd -95	Ext. Conc -94	Ext. Conc -95	Mat Conc -94	Mat Conc -95
1419	Grnd	PR	1	4878	-	2453	-	1094	2322	-	-
1429	Mad	PR	1	-	-	-	-	1107	1771	3635	834
1408	State	PR	1	638	-	624	-	551	1285	-	-

Notes: Remediation codes: PR = previously remediated (Nov. 1993); R = prior to remediation, Nov. 1994; AR= immediately after remediation, Nov. 1994.

APPENDIX TABLE 2
SUMMARY OF SOIL AND PAINT LEAD CHANGES, 1994-1995

Number	Street	Remediation	Code	Soil Peri -94	Soil Peri -95	Soil Curb -94	Soil Curb -95	Pnt Conc %-94	Pnt Conc %-95	Ext. XRF -94	Int. XRF -94
1412	Grnd	R	9	3635	222	2243	29	-	<.01	10.1	3.6
1415	Grnd	R	9	1089	622	1782	31	-	-	18.1	0.7
1418	Grnd	R	9	2065	490	4840	85	0.29	32.1	38.6	39.2
1424	Grnd	R	9	2852	38	2869	64	2.31	0.47	13.2	2.3
1431	Grnd	R	9	1250	1235	2247	80	15.7	<.01	21.8	2.5
1410	Grnd	PR	8	32	56	2159	1283	-	<.01	1.8	0.5
1443	Grnd	PR	8	630	3845	1133	764	-	-	2.8	0.9

APPENDIX TABLE 2 (continued)
SUMMARY OF SOIL AND PAINT LEAD CHANGES, 1994-1995

Number	Street	Remediation	Code	Soil Peri -94	Soil Peri -95	Soil Curb -94	Soil Curb -95	Pnt Conc %-94	Pnt Conc %-95	Ext. XRF -94	Int. XRF -94
1406	State	AR	7	26	42	24	135	-	<.01	0.4	2.5
1413	Mad	AR	3	30	69	190	53	4.15	<.01	-	-
1415	Mad	AR	3	28	681	90	76	-	0.24	8.9	-
1429	Grnd	R	2	2330	75	2193	47	-	<.01	28.3	0.5
1436	Grnd	R	2	938	2158	2967	71	-	<.01	9.1	5.5
1438	Grnd	R	2	10K	4154	1838	2094	4.05	16.9	17.1	-

APPENDIX TABLE 2 (continued)
SUMMARY OF SOIL AND PAINT LEAD CHANGES, 1994-1995

Number	Street	Remediation	Code	Soil Peri -94	Soil Peri -95	Soil Curb -94	Soil Curb -95	Pnt Conc %-94	Pnt Conc %-95	Ext. XRF -94	Int. XRF -94
1425	Mad	R	2	1868	82	1420	1448	2.85	14.3	18.9	5.5
1419	Grnd	PR	1	1312	654	3124	60	2.75	3.39	17.3	1.8
1429	Mad	PR	1	104	117	2351	1754	-	<.01	39.8	-

Notes: Remediation codes: PR = previously remediated (Nov. 1993); R = prior to remediation, Nov. 1994; AR= immediately after remediation, Nov. 1994.