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DRAFT REPORT

STATISTICAL EVALUATION OF THE RELATIONSHIP BETWEEN BLOOD-LEAD AND DUST-LEAD BASED ON DATA FROM THE ROCHESTER LEAD-IN-DUST STUDY

for

Task 4-13

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STATISTICAL EVALUATION OF THE RELATIONSHIP BETWEEN BLOOD-LEAD AND DUST-LEAD BASED ON DATA FROM THE ROCHESTER LEAD-IN-DUST STUDY

1.0 INTRODUCTION

The following statistical analysis investigated the relationship between children's blood-lead concentrations and levels of lead in interior household dust from data collected in the Rochester Lead-in-Dust Study. This research was conducted to support regulatory decisions for Section 403 of Title X being made by EPA's Office of Pollution Prevention and Toxics. Specifically, this research was designed to give information on the levels of interior dust lead found on floors, window sills or window wells that would result in 85%, 90%, 95% and 99% of the distribution of childhood blood-lead concentrations being below 10, 15, and 20 µg/dL. Additionally this analysis investigated the importance of levels of lead in window well dust as a predictor of blood-lead concentrations after taking into account the levels of lead in floor and window sill dust.

This analysis follows a similar approach to that taken for an analysis of data from the Repair and Maintenance (R&M) Study, and the results are presented in the same format so that comparisons between the two studies can be made.

2.0 DATA PREPARATION

The sample consisted of 205 homes with one child per home. The response variable in the statistical analysis was the natural logarithm of child blood-lead concentration measured in units of ln(µg/dL). Predictor variables included lead loading and concentration results observed in dust from floors, window sills and window wells, and the date of blood sampling which was used to account for time trends in blood-lead concentrations. In 204 homes, blood samples and dust samples were all collected within a three-week window of time. For one home the dust sampling date was not available.

Individual samples of dust lead were collected from multiple locations of a given component type using both the Baltimore R&M (BRM) vacuum sampling method and wipe sampling. The samples were often collected from locations with different surface areas. For example, homes with uncarpeted floors had between 1 and 5 floor BRM dust samples with total area ranging from 1 to 5 ft^2 sampled per house. Each house also had 1 to 3 window sill BRM samples with total area ranging from 0.06 to 1.7 ft^2 sampled per house. In addition, each house had between 1 and 3 window well BRM samples with total area ranging from 0.05 to 1.2 ft^2 sampled per house. Since the area and mass of each individual sample varied within a house, area weighted average lead loading and mass weighted average lead concentration results were calculated for floors, window sills and window wells. Thus, if two dust samples were collected from floor locations within a house with sample areas of 1 ft^2 and 3 ft^2, the lead loading results from the 3 ft^2 sample were weighted by a factor of 3 when calculating the area weighted averages. The natural log of these weighted average lead loading and concentration results were used as predictor variables in the statistical analyses, and therefore the estimated relationships between blood lead and dust lead correspond to dust lead averages and not individual 'hot spots'.

Floor samples in the Rochester Lead-in-Dust Study were collected from both carpeted and uncarpeted surfaces, while floor samples in the R&M Study were collected from only uncarpeted surfaces. Therefore, to maintain comparability analysis of the Rochester data was restricted to the data for uncarpeted surfaces. From the original sample of 205 Rochester homes, there were a total of 193 homes with BRM floor-dust samples collected from uncarpeted floor surfaces.

The median blood-lead level from all 205 homes was 6.1 $\mu g/dL$ (range 1.4 to 31.7 $\mu g/dL$). The median BRM floor dust-lead loading from the 193 homes with uncarpeted floors was 13.2 $\mu g/ft^2$ (range 0.1 to 74,100 $\mu g/ft^2$). The median window sill BRM dust-lead loading from 197 homes was 265 $\mu g/ft^2$ (range 0.7 to 118,000

$\mu g/ft^2$). The median window well BRM dust-lead loading from 189 homes was 48,000 $\mu g/ft^2$ (range 7 to 3,000,000 $\mu g/ft^2$).

3.0 THE STATISTICAL MODEL

A log-linear statistical model was used which expresses blood-lead concentrations as a function of environmental lead levels. Specifically, the model contains a single intercept, a single slope relating ln(blood lead) to ln(dust lead) and a time effect which adjusts for temporal trends in childhood blood-lead concentrations. Since the dates of environmental sampling ranged from August 31, 1993 to November 20, 1993 in the Rochester Lead-in-Dust Study, there was not a large enough range of time points to properly parameterize the sine-wave model for seasonal variations in blood-lead that was used in the analysis of the Repair and Maintenance Study data. Therefore, a simple linear trend was fitted to capture the seasonal variations in the Rochester data between August 31 and November 20, 1993. Details concerning the mathematical form of the statistical model can be found in Appendix A.

Due to the fact that environmental lead levels are usually measured with error, both a simple least-squares approach (which does not account for measurement error) and a statistical approach that adjusts for measurement error in predictor variables were used while fitting the statistical model. Details concerning the statistical adjustment for errors in predictor variables can be found in Appendix B.

The model used makes a simplifying assumption about the Rochester Lead-in-Dust Study data. In particular, this analysis does not attempt to account for the possible effect of potentially important socioeconomic and behavioral factors. Investigators in the Rochester Lead-in-Dust Study found that four covariates were "significantly associated with higher blood lead levels among children: Black race, parental reports that children put soil in their mouths, single parent household, and a higher ferritin level".[1]

4.0 STATISTICAL MODELING RESULTS

The results of fitting the statistical model to the data using an errors in variables approach are reported in Table 1. Separate models were fitted for the nine environmental-lead (PbE) measurements -- lead loading by BRM and wipe sampling for uncarpeted floors, window sills, and window wells, as well as lead concentration by BRM sampling for uncarpeted floors, window sills, and window wells. Slope (β_1) parameter estimates and associated 95% confidence intervals are reported, as well as a measure of the proportion of variability explained by the model (R^2) from a 'least squares' fit of the model.

The relationship between blood-lead concentrations and dust lead loadings for floors, window sills, and window wells are illustrated graphically in Figures 1 through 9. The fitted regression curve from the least-squares fit is plotted using a finely dashed line, and the solution from the errors in variables model is plotted using a solid line. The four upper dashed curves in Figures 1 to 9 represent upper 95% tolerance bounds for the 85th, 90th, 95th, and 99th percentiles of the distribution of children's blood-lead concentration as a function of dust-lead loadings. The line type employing the shortest dash corresponds to the 85th percentile, the next shortest corresponds to the 90th percentile, and so on. The estimated regression curves and associated tolerance bounds were calculated for children's blood-lead levels measured near the median sampling date (October 13,

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[1]Department of Pediatrics, Biostatistics, and Environmental Medicine, The University of Rochester School of Medicine, (June, 1995), "The Relation of Lead-Contaminated House Dust and Blood Lead Levels Among Urban Children, Final Report, Volume II, Results and Discussion", U.S. Department of Housing and Urban Development Grant No. MLDP T0001-93.

Table 1. Results of Fitting the Statistical Model to the Rochester Lead-in-Dust Data Using the Errors in Variables Approach

Unit of Measure	Component Tested	Slope Values: β_1 Slope Estimate	Slope Values: 95% Confidence Interval	R^2 (a)
Slope Values in Units of ln(μg Pb / dL Blood) / ln(μg Pb / ft² Sampled) (BRM Sampler)				
Loading (μg/ft²)	Floors	0.133	(0.089 , 0.177)	0.139
	Window Sills	0.126	(0.087 , 0.165)	0.139
	Window Wells	0.149	(0.115 , 0.183)	0.160
Slope Values in Units of ln(μg Pb / dL Blood) / ln(μg Pb / ft² Sampled) (Wipe Samples)				
Loading (μg/ft²)	Floors	0.237	(0.155 , 0.319)	0.111
	Window Sills	0.198	(0.133 , 0.264)	0.131
	Window Wells	0.179	(0.130 , 0.229)	0.108
Slope Values in Units of ln(μg Pb / dL Blood) / ln(μg Pb / g Dust) (BRM Sampler)				
Concentration (μg/g)	Floors	0.104	(0.033 , 0.175)	0.033
	Window Sills	0.126	(0.077 , 0.175)	0.083
	Window Wells	0.111	(0.062 , 0.161)	0.066

(a) The reported R^2 values are based on a least squares fit without adjusting for the errors in predictor variables.

(b) Based on the results of this simple descriptive model, the predicted blood-lead concentration for children living in houses with BRM floor lead loadings of 100 and 200 μg.ft² would be 7.6 and 8.3 μg/dL respectively for a difference of 0.7 μg/dL.

1993). Methods for calculating the tolerance bounds are detailed in Appendix C. The tolerance bounds depicted in these figures represent a 95% upper confidence bound for the 85th, 90th, 95th and 99th percentiles of the distribution of children's blood-lead concentrations at each dust-lead level, based on the regression model results. Thus, the highest curve in Figure 1 corresponds to a 95% upper confidence bound on the 99th percentile of children as a function of BRM floor-lead loading.

5.0 PROTECTIVE DUST LEAD LEVELS

The dashed curves in Figures 1 to 9 can be used to determine the levels of interior dust lead that would result in 85%, 90%, 95% and 99% of the distribution of childhood blood-lead concentrations being below target values with 95% confidence. This is accomplished by drawing a horizontal line at the blood-lead level of interest, and then drawing a vertical line at the point of intersection with the appropriate tolerance bound curve.

Table 2 reports such dust-lead loading levels for floors, window sills and wells based on target blood-lead levels of 10, 15, and 20 μg/dL. The results in this table are based on tolerance bounds calculated using the errors in variables model at or near the median sampling date (October 13, 1993).

In some cases, the tolerance bound is higher than the blood-lead level of interest over the entire range of plausible dust-lead levels. For example in Figure 1, the tolerance bound for the 99th percentile of children's blood-lead concentrations is always above a blood-lead concentration of 10 μg/dL. In Table 2 these cases have associated dust-lead values that are listed as "Out of Range".

6.0 EXCEEDANCE PROPORTIONS

Table 3 provides estimates of the proportion of children with blood-lead concentrations exceeding 10, 15, and 20 μg/dL at various targeted dust-lead loading values for floors, window sills, and window wells. These exceedance proportions, and associated 95% confidence intervals were calculated using methods detailed in Appendix C. They are based on the errors in variables model near the median sampling date (October 13, 1993).

The results from this analysis suggest that for BRM dust-lead loadings of 100 $\mu g/ft^2$ on floors, 500 $\mu g/ft^2$ on window sills, and 800 $\mu g/ft^2$ on window wells, approximately 31%, 19%, and 2% of the children sampled in this study would be expected to have blood-lead concentrations that exceed 10 μg/dL at the median sampling date (October 13, 1993).

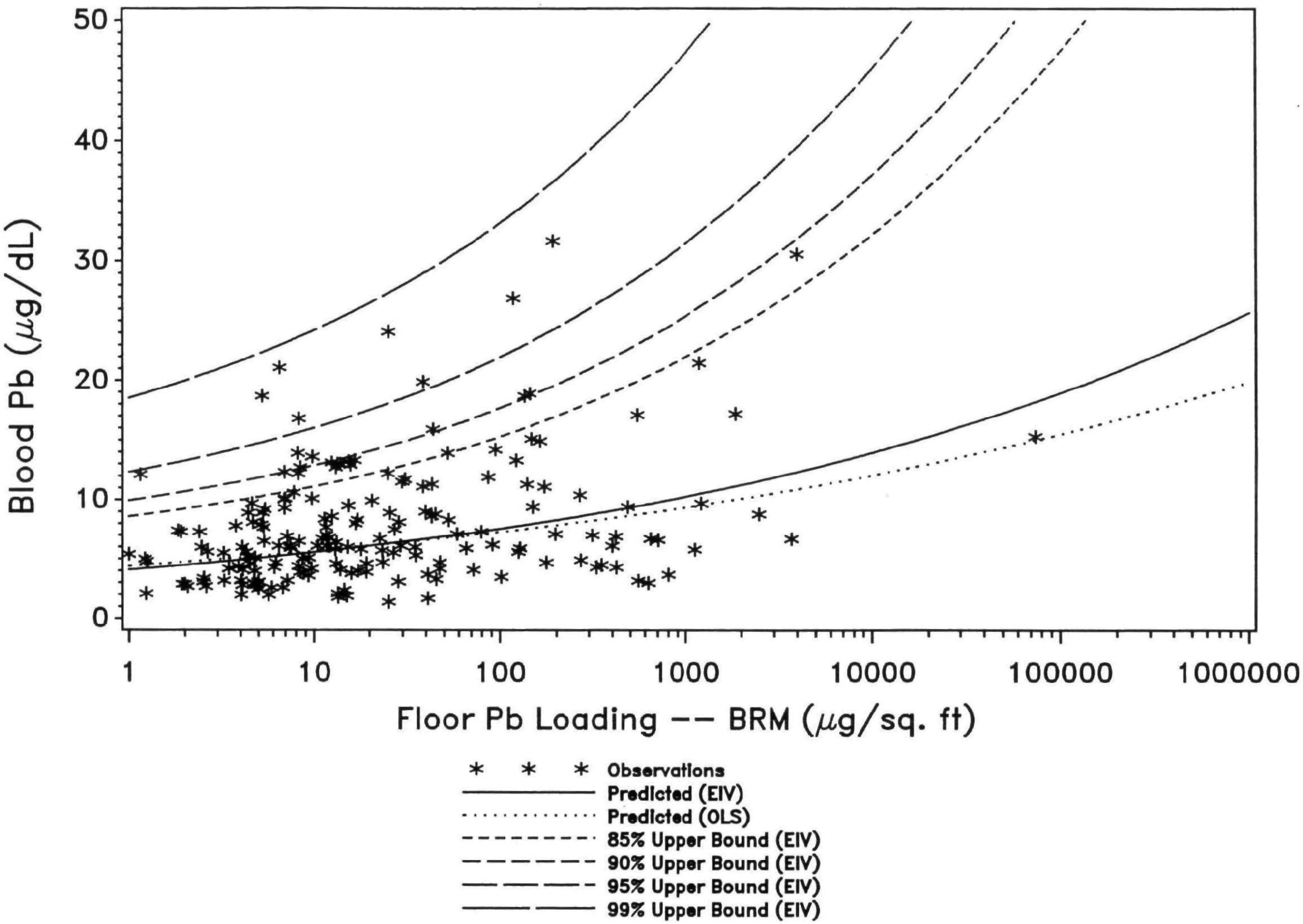

Figure 1. Rochester Lead-in-Dust Study Floor-Lead Loadings From BRM Sampling -- Estimated Regression Curve and Tolerance Bounds for the 85th, 90th, 95th, and 99th Percentiles of Children's Blood-Lead Concentrations Based on Errors in Variables Fit.

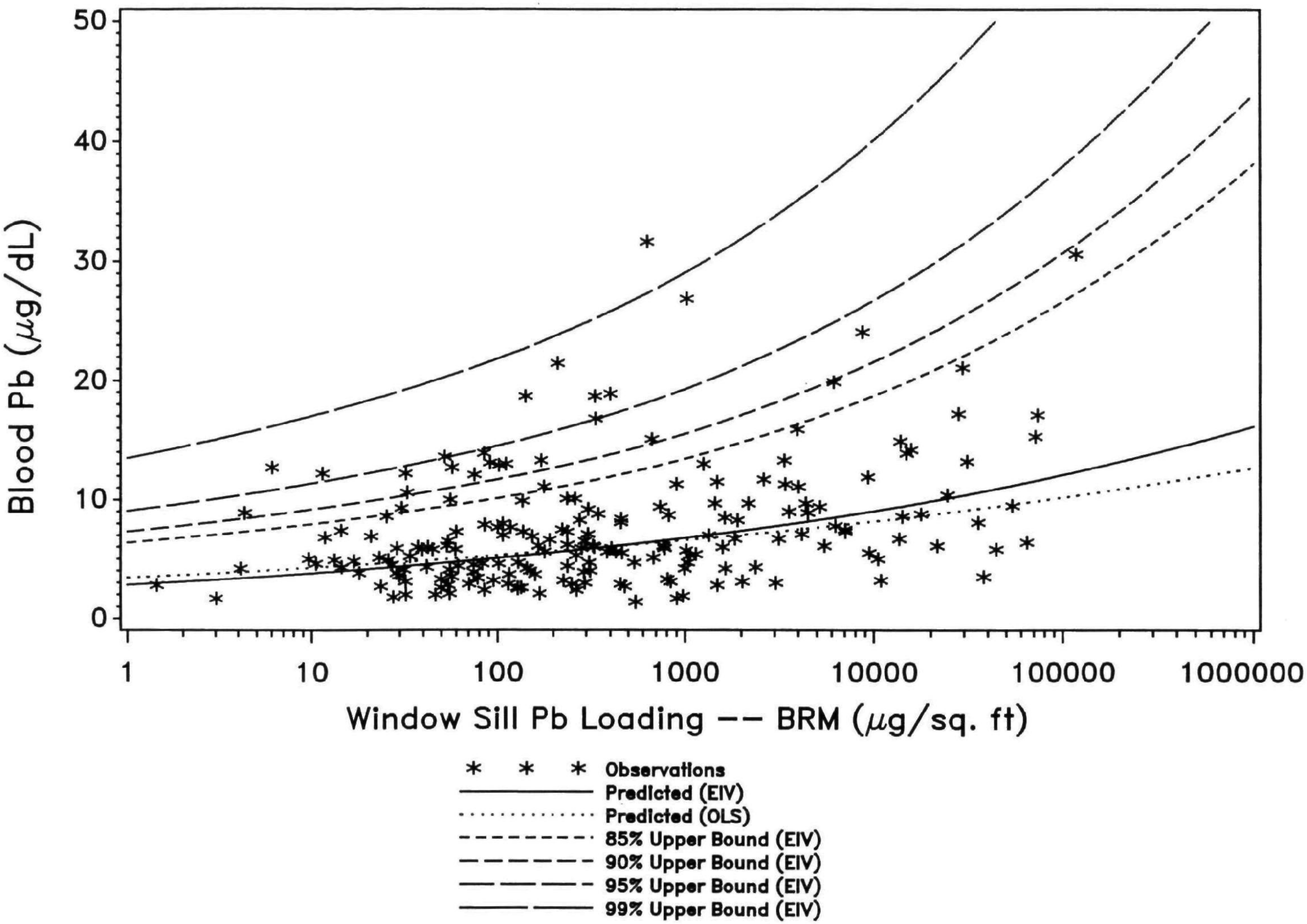

Figure 2. Rochester Lead-in-Dust Study Window Sill-Lead Loadings From BRM Sampling -- Estimated Regression Curve and Tolerance Bounds for the 85th, 90th, 95th, and 99th Percentiles of Children's Blood-Lead Concentrations Based on Errors in Variables Fit.

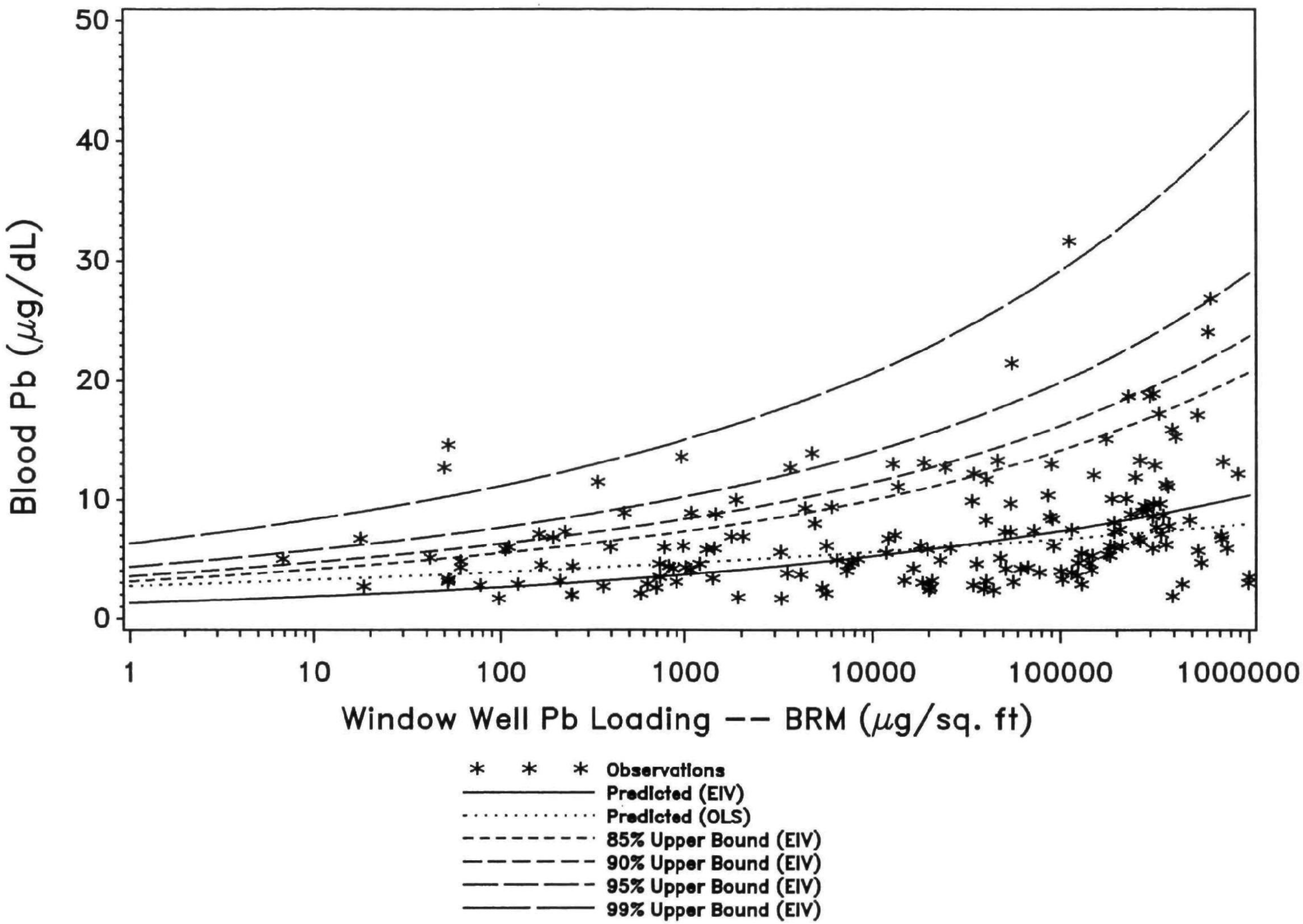

Figure 3. Rochester Lead-in-Dust Study Window Well-Lead Loadings From BRM Sampling -- Estimated Regression Curve and Tolerance Bounds for the 85th, 90th, 95th, and 99th Percentiles of Children's Blood-Lead Concentrations Based on Errors in Variables Fit.

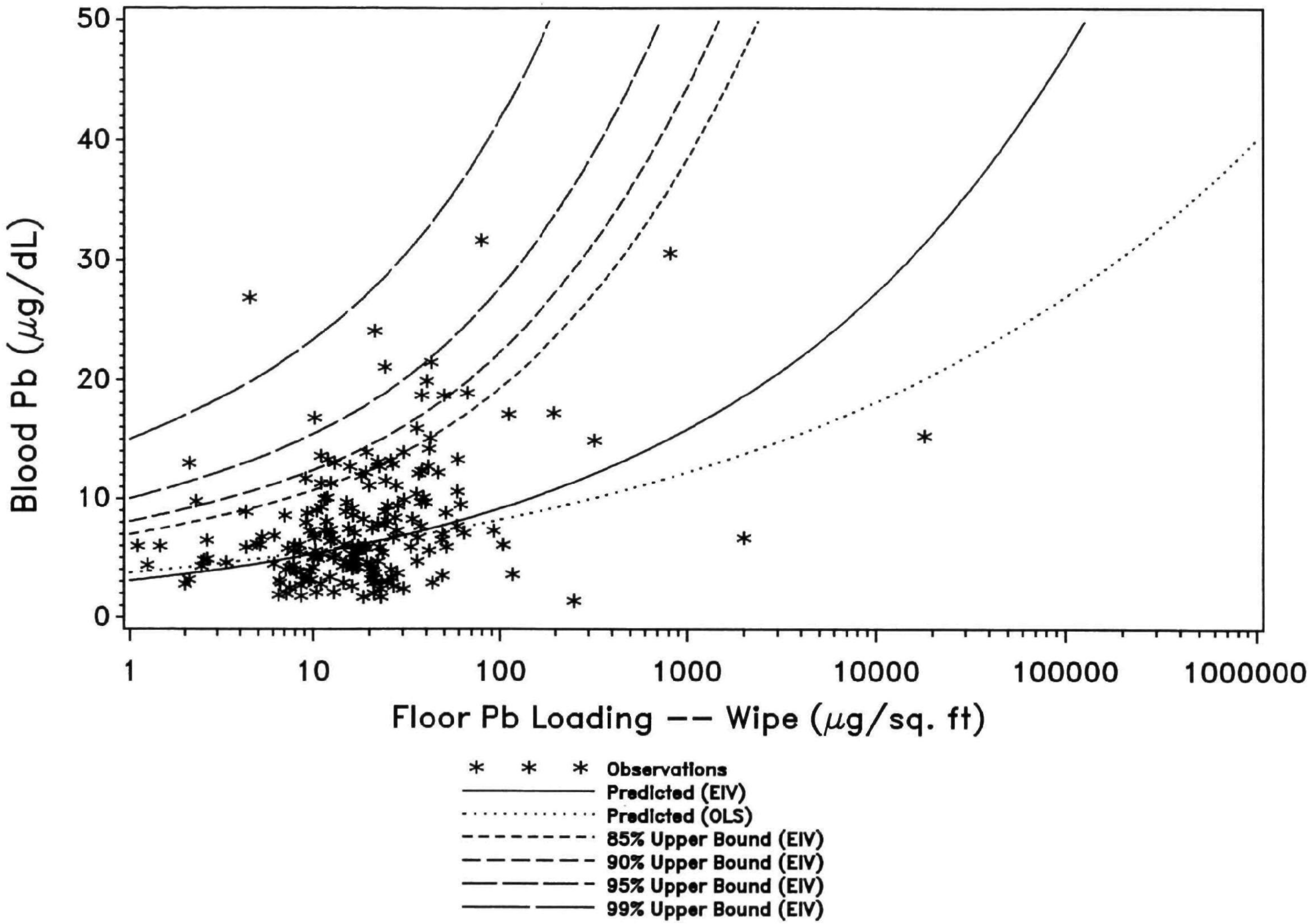

Figure 4. Rochester Lead-in-Dust Study Floor-Lead Loadings From Wipe Sampling -- Estimated Regression Curve and Tolerance Bounds for the 85th, 90th, 95th, and 99th Percentiles of Children's Blood-Lead Concentrations Based on Errors in Variables Fit.

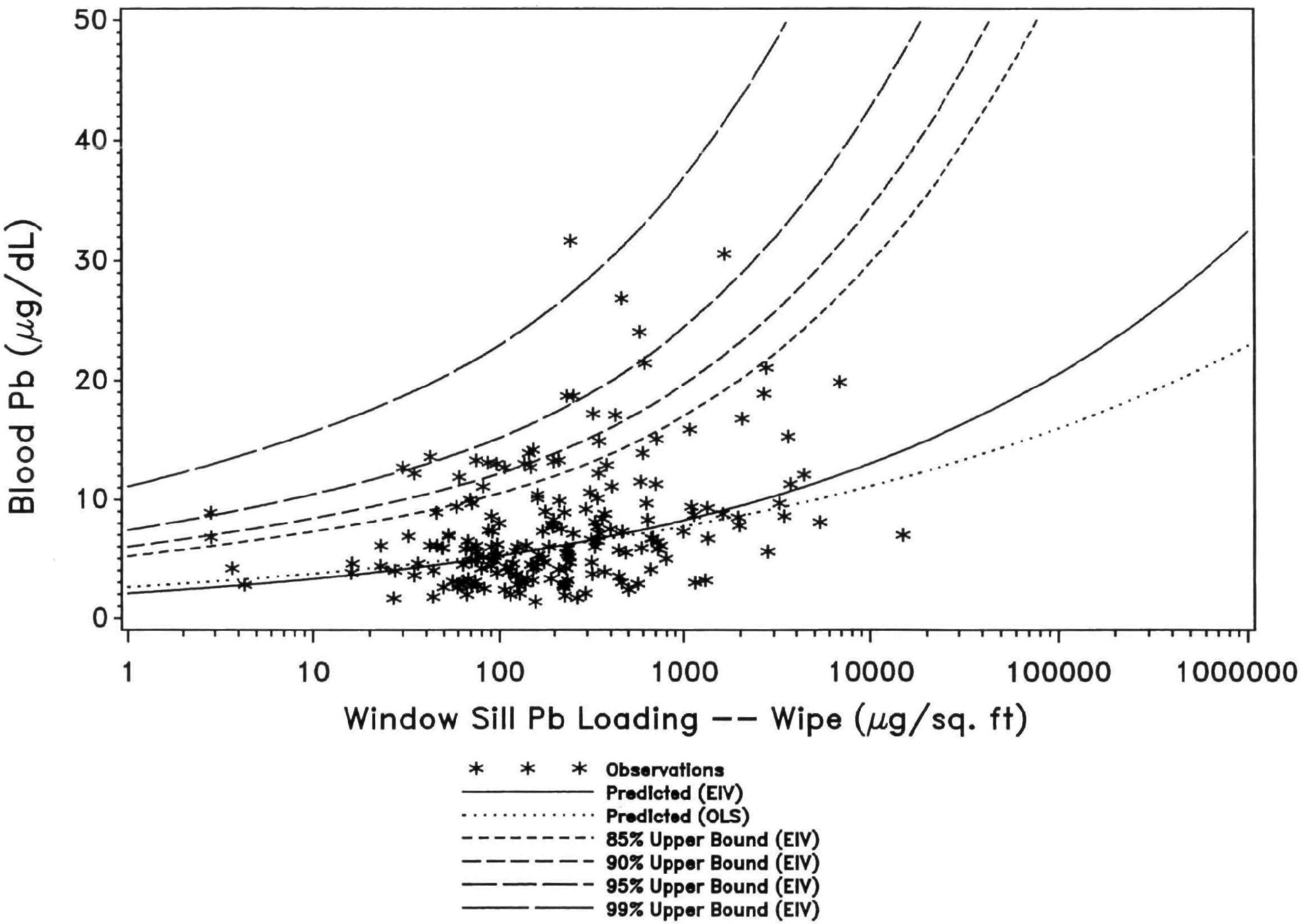

Figure 5. Rochester Lead-in-Dust Study Window Sill-Lead Loadings From Wipe Sampling -- Estimated Regression Curve and Tolerance Bounds for the 85th, 90th, 95th, and 99th Percentiles of Children's Blood-Lead Concentrations Based on Errors in Variables Fit.

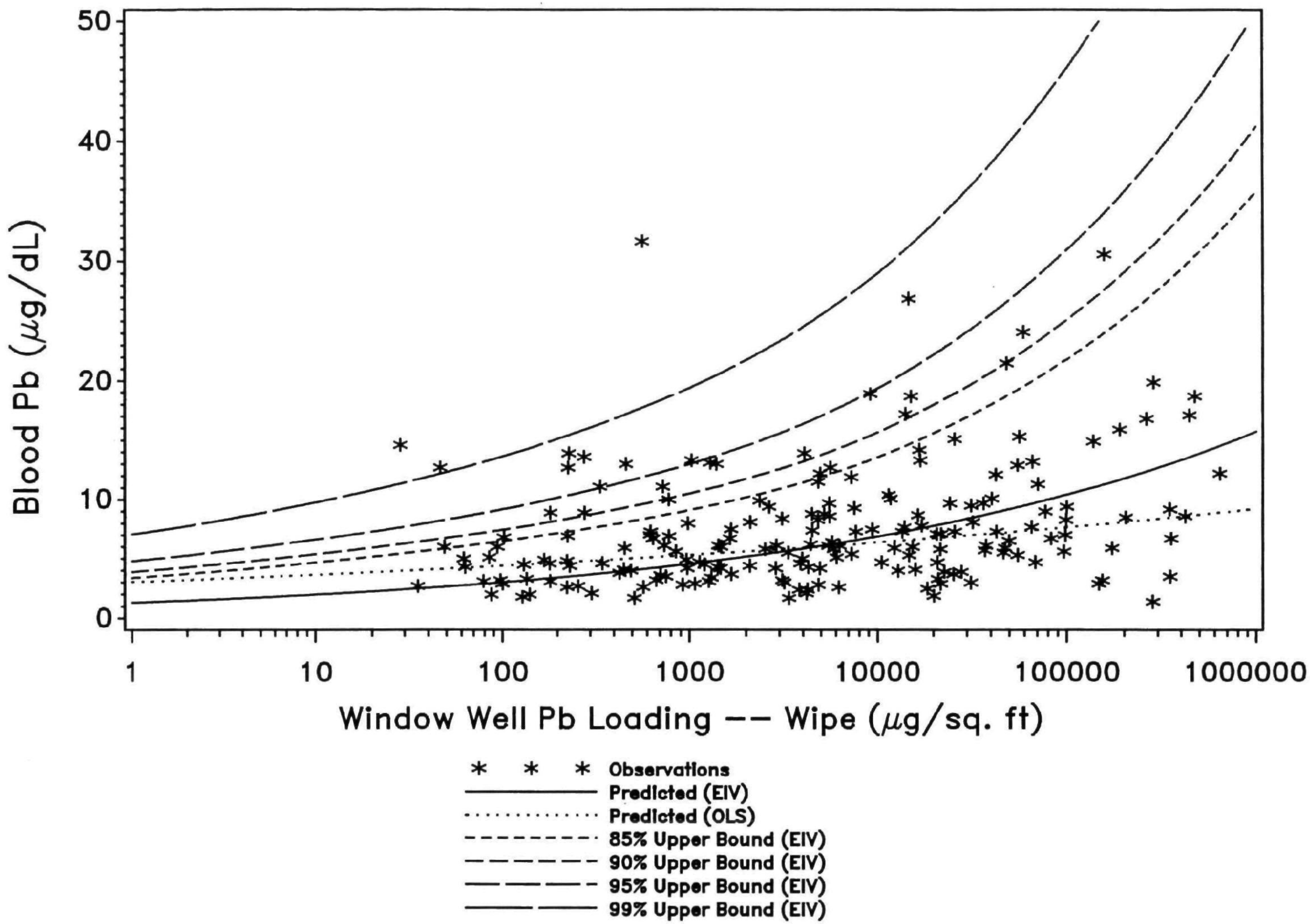

Figure 6. Rochester Lead-in-Dust Study Window Well-Lead Loadings From Wipe Sampling -- Estimated Regression Curve and Tolerance Bounds for the 85th, 90th, 95th, and 99th Percentiles of Children's Blood-Lead Concentrations Based on Errors in Variables Fit.

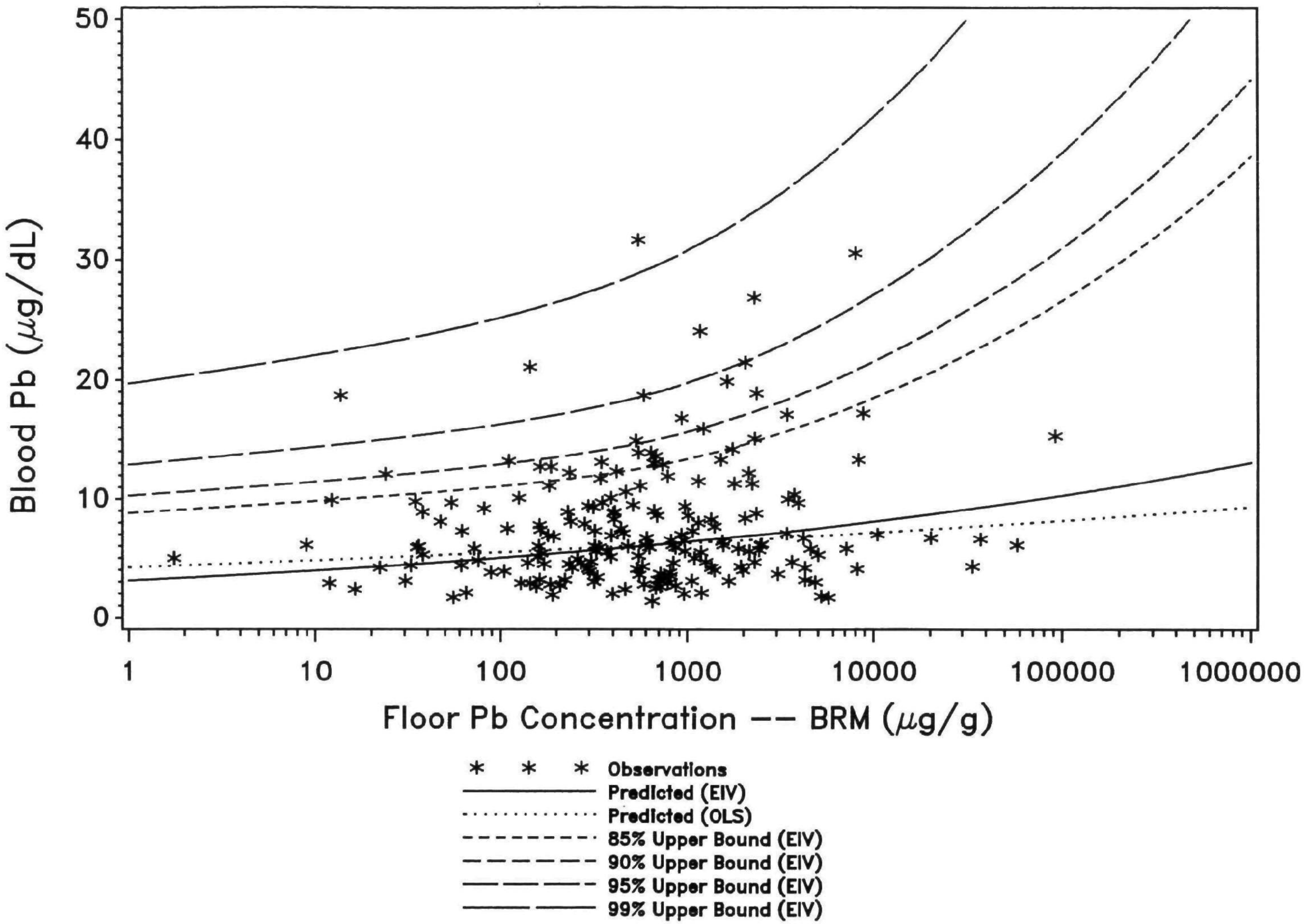

Figure 7. Rochester Lead-in-Dust Study Floor-Lead Concentrations From BRM Sampling -- Estimated Regression Curve and Tolerance Bounds for the 85th, 90th, 95th, and 99th Percentiles of Children's Blood-Lead Concentrations Based on Errors in Variables Fit.

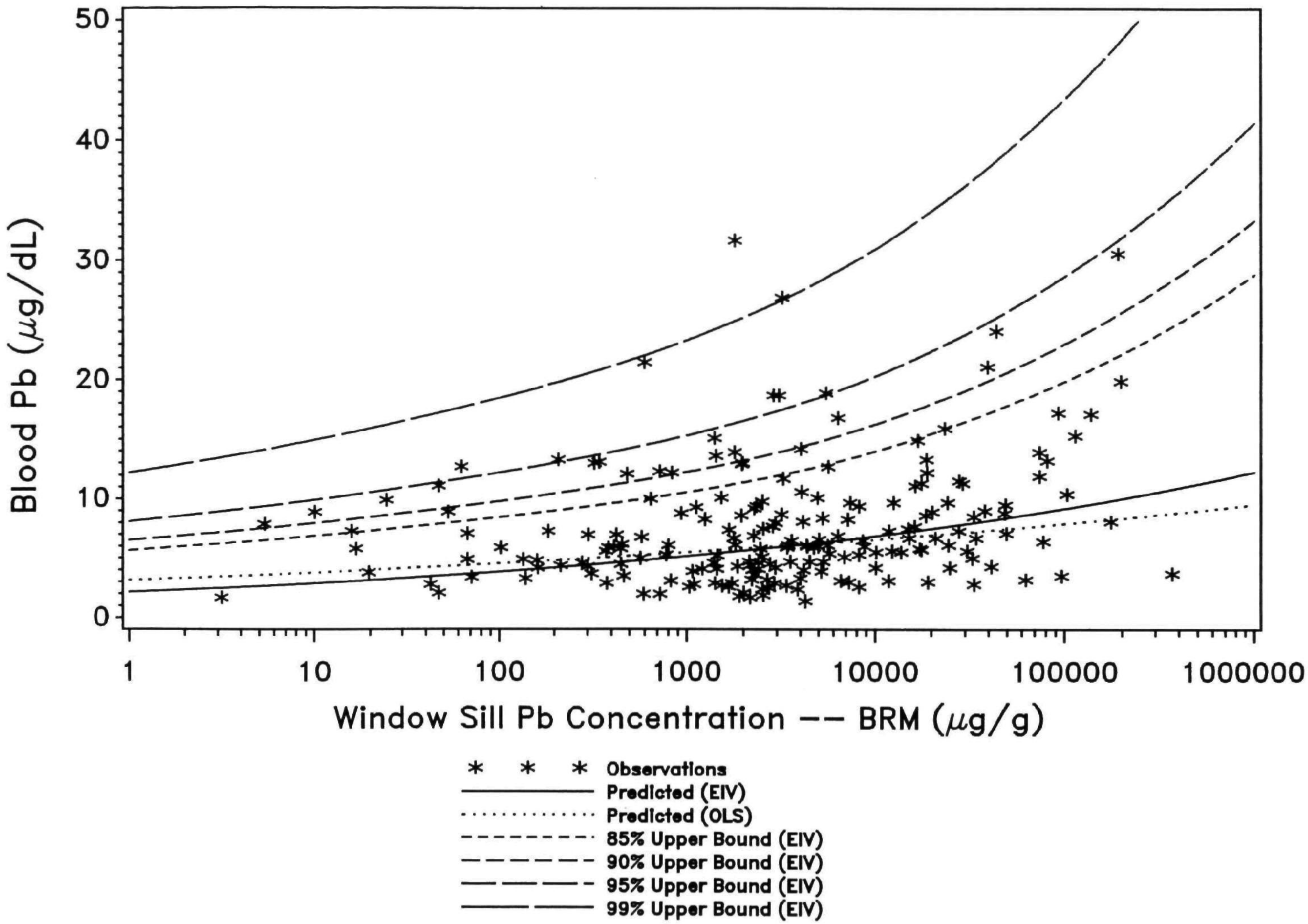

Figure 8. Rochester Lead-in-Dust Study Window Sill-Lead Concentrations From BRM Sampling -- Estimated Regression Curve and Tolerance Bounds for the 85th, 90th, 95th, and 99th Percentiles of Children's Blood-Lead Concentrations Based on Errors in Variables Fit.

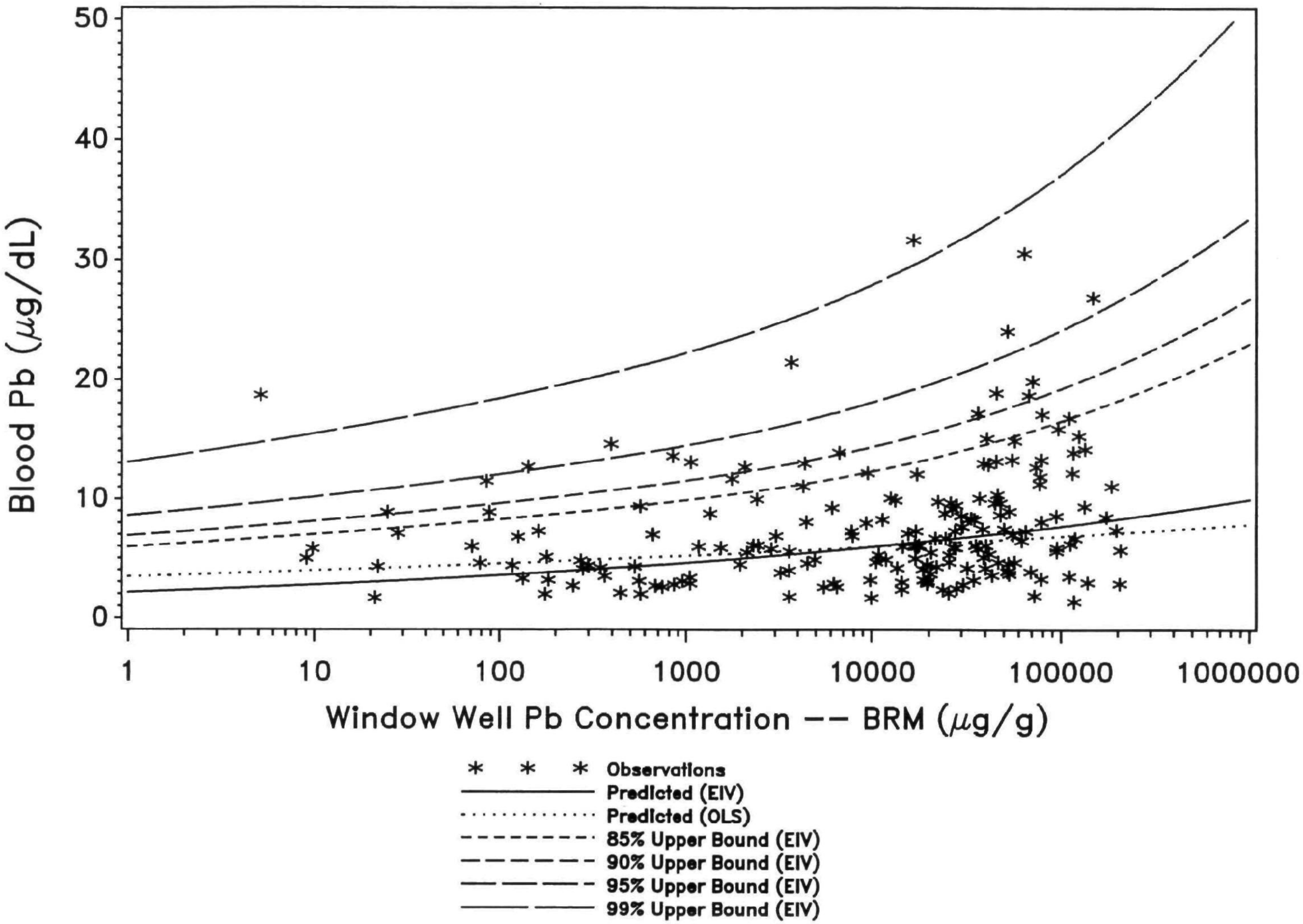

Figure 9. Rochester Lead-in-Dust Study Window Well-Lead Concentrations From BRM Sampling -- Estimated Regression Curve and Tolerance Bounds for the 85th, 90th, 95th, and 99th Percentiles of Children's Blood-Lead Concentrations Based on Errors in Variables Fit.

Table 2. Estimated Dust Lead Levels for Floors, Window Sills, and Window Wells at Which the 85th, 90th, 95th, and 99th Percentiles of Childhood Blood Lead Concentrations Reach 10, 15, and 20 μg/dL (Based on the Errors in Variables Approach)

BRM Sampler Lead Loading

Sample Type	Tolerance Level	Target Blood-Lead Concentration		
		10 μg/dL	15 μg/dL	20 μg/dL
Floor Pb Loading (μg/ft²) BRM Sampler	0.85	4	88	553
	0.90	1	32	223
	0.95	Out of Range	5	52
	0.99	Out of Range	Out of Range	1
Window Sill Pb Loading (μg/ft²) BRM Sampler	0.85	89	2,209	15,477
	0.90	23	770	5,938
	0.95	2	133	1,307
	0.99	Out of Range	2	45
Window Well Pb Loading (μg/ft²) BRM Sampler	0.85	10,156	144,436	805,938
	0.90	3,779	61,592	362,045
	0.95	817	15,940	104,728
	0.99	41	982	8,045
Wipe Sampling Lead Loading				
Floor Pb Loading (μg/ft²) Wipe Samples	0.85	7	40	112
	0.90	3	23	67
	0.95	Out of Range	8	30
	0.99	Out of Range	Out of Range	4
Window Sill Pb Loading (μg/ft²) Wipe Samples	0.85	74	578	1,965
	0.90	30	294	1,068
	0.95	7	93	405
	0.99	Out of Range	7	45
Window Well Pb Loading (μg/ft²) Wipe Samples	0.85	1,799	16,621	66,800
	0.90	732	7,989	33,992
	0.95	179	2,420	11,785
	0.99	11	190	1208

Table 2. Continued

BRM Sampler Lead Concentration

Sample Type	Tolerance Level	Target Blood-Lead Concentration		
		10 µg/dL	15 µg/dL	20 µg/dL
Floor Pb Concentration (µg/g) BRM Sampler	0.85	14	2,450	16,581
	0.90	Out of Range	685	6,088
	0.95	Out of Range	23	1,106
	0.99	Out of Range	Out of Range	1
Window Sill Pb Concentration (µg/g) BRM Sampler	0.85	593	16,270	104,638
	0.90	125	5,586	40,827
	0.95	11	830	8,974
	0.99	Out of Range	10	228
Window Well Pb Concentration (µg/g) BRM Sampler	0.85	1,104	49,044	378,000
	0.90	162	14,463	131,306
	0.95	8	1,488	23,482
	0.99	Out of Range	6	280

[a] A result of 'Out of Range' indicates that the tolerance bound for Blood-Pb is always above the target level.

Results are based on a time adjusted analysis held fixed at October 13, which was the median sampling date.

Table 3. Estimated Proportion of Children with Blood-Lead Concentrations Greater than 10, 15, and 20 µg/dL as a Function of Floor, Window Sill, or Window Well Lead Loadings (Based on the Errors in Variables Approach)

BRM Sampler Lead Loading

Surface Tested	Pb Loading µg/ft²	Proportion Greater Than 10 µg/dl		Proportion Greater Than 15 µg/dl		Proportion Greater Than 20 µg/dl	
		Pr(Pb>10)	95% CI	Pr(Pb>15)	95% CI	Pr(Pb>20)	95% CI
Floors	5	0.11	(0.07 , 0.16)	0.02	(0.01 , 0.05)	0.00	(0.00 , 0.01)
	10	0.15	(0.10 , 0.20)	0.04	(0.02 , 0.06)	0.01	(0.00 , 0.02)
	15	0.17	(0.12 , 0.22)	0.04	(0.02 , 0.07)	0.01	(0.00 , 0.02)
	20	0.19	(0.14 , 0.24)	0.05	(0.03 , 0.08)	0.01	(0.00 , 0.03)
	25	0.20	(0.15 , 0.26)	0.06	(0.03 , 0.09)	0.02	(0.01 , 0.03)
	30	0.21	(0.16 , 0.27)	0.06	(0.04 , 0.10)	0.02	(0.01 , 0.04)
	35	0.22	(0.17 , 0.29)	0.07	(0.04 , 0.10)	0.02	(0.01 , 0.04)
	40	0.23	(0.18 , 0.30)	0.07	(0.04 , 0.11)	0.02	(0.01 , 0.04)
	100	0.31	(0.24 , 0.38)	0.11	(0.07 , 0.16)	0.04	(0.02 , 0.07)
	200	0.37	(0.28 , 0.46)	0.14	(0.09 , 0.21)	0.06	(0.03 , 0.10)
	250	0.39	(0.29 , 0.49)	0.16	(0.10 , 0.23)	0.06	(0.03 , 0.11)
Window Sills	50	0.08	(0.05 , 0.13)	0.01	(0.00 , 0.03)	0.00	(0.00 , 0.01)
	100	0.11	(0.07 , 0.16)	0.02	(0.01 , 0.04)	0.00	(0.00 , 0.01)
	200	0.14	(0.10 , 0.19)	0.03	(0.02 , 0.06)	0.01	(0.00 , 0.02)
	300	0.16	(0.12 , 0.22)	0.04	(0.02 , 0.07)	0.01	(0.00 , 0.02)
	400	0.18	(0.13 , 0.23)	0.05	(0.03 , 0.08)	0.01	(0.00 , 0.03)
	500	0.19	(0.14 , 0.25)	0.05	(0.03 , 0.09)	0.01	(0.00 , 0.03)
	600	0.20	(0.15 , 0.26)	0.06	(0.03 , 0.09)	0.02	(0.01 , 0.03)
	700	0.21	(0.16 , 0.27)	0.06	(0.04 , 0.10)	0.02	(0.01 , 0.04)
Window Wells	200	0.00	(0.00 , 0.02)	0.00	(0.00 , 0.00)	0.00	(0.00, 0.00)
	500	0 01	(0.00 , 0.04)	0.00	(0.00 , 0.00)	0.00	(0.00 , 0.00)
	750	0.02	(0.01 , 0.05)	0.00	(0.00 , 0.00)	0.00	(0.00 , 0.00)
	800	0.02	(0.01 , 0.05)	0.00	(0.00 , 0.01)	0.00	(0.00 , 0.00)
	1500	0.03	(0.01 , 0.07)	0.00	(0.00 , 0.01)	0.00	(0.00 , 0.00)
	3000	0.05	(0.03 , 0.09)	0.00	(0.00 , 0.02)	0.00	(0.00 , 0.00)
	5000	0.07	(0.04 , 0.12)	0.01	(0.00 , 0.02)	0.00	(0.00 , 0.00)
	10000	0.10	(0.07 , 0.15)	0.02	(0.01 , 0.04)	0.00	(0.00 , 0.01)
	20000	0.15	(0.10 , 0.20)	0.03	(0.02 , 0.06)	0.00	(0.00 , 0.02)

Table 3. Continued

Wipe Sampling Lead Loading

Surface Tested	Pb Loading $\mu g/ft^2$	Proportion Greater Than 10 $\mu g/dl$		Proportion Greater Than 15 $\mu g/dl$		Proportion Greater Than 20 $\mu g/dl$	
		Pr(Pb>10)	95% CI	Pr(Pb>15)	95% CI	Pr(Pb>20)	95% CI
Floors	5	0.08	(0.04 , 0.13)	0.01	(0.00 , 0.03)	0.00	(0.00 , 0.01)
	10	0.13	(0.09 , 0.18)	0.03	(0.01 , 0.06)	0.01	(0.00 , 0.02)
	15	0.17	(0.12 , 0.22)	0.04	(0.02 , 0.07)	0.01	(0.00 , 0.03)
	20	0.20	(0.15 , 0.26)	0.06	(0.03 , 0.09)	0.02	(0.01 , 0.03)
	25	0.23	(0.18 , 0.29)	0.07	(0.04 , 0.11)	0.02	(0.01 , 0.04)
	30	0.25	(0.20 , 0.32)	0.08	(0.05 , 0.12)	0.03	(0.01 , 0.05)
	35	0.27	(0.21 , 0.34)	0.09	(0.06 , 0.14)	0.03	(0.01 , 0.06)
	40	0.29	(0.23 , 0.37)	0.1	(0.06 , 0.15)	0.04	(0.02 , 0.06)
	100	0.44	(0.32 , 0.55)	0.19	(0.12 , 0.28)	0.08	(0.04 , 0.14)
	200	0.55	(0.40 , 0.69)	0.28	(0.16 , 0.42)	0.14	(0.07 , 0.24)
	250	0.59	(0.42 , 0.73)	0.31	(0.18 , 0.47)	0.16	(0.08 , 0.28)
Window Sills	50	0.08	(0.04 , 0.13)	0.01	(0.00 , 0.03)	0.00	(0.00 , 0.01)
	100	0.12	(0.08 , 0.18)	0.03	(0.01 , 0.05)	0.00	(0.00 , 0.02)
	200	0.18	(0.13 , 0.24)	0.05	(0.03 , 0.08)	0.01	(0.00 , 0.03)
	300	0.22	(0.17 , 0.28)	0.07	(0.04 , 0.10)	0.02	(0.01 , 0.04)
	400	0.25	(0.19 , 0.32)	0.08	(0.05 , 0.12)	0.03	(0.01 , 0.05)
	500	0.28	(0.21 , 0.35)	0.09	(0.06 , 0.14)	0.03	(0.01 , 0.06)
	600	0.30	(0.23 , 0.38)	0.11	(0.07 , 0.16)	0.04	(0.02 , 0.07)
	700	0.32	(0.24 , 0.40)	0.12	(0.07 , 0.17)	0.04	(0.02 , 0.08)
Window Wells	200	0.02	(0.00 , 0.05)	0.00	(0.00 , 0.01)	0.00	(0.00 , 0.00)
	500	0.05	(0.02 , 0.09)	0.00	(0.00 , 0.02)	0.00	(0.00 , 0.00)
	750	0.06	(0.03 , 0.10)	0.01	(0.00 , 0.02)	0.00	(0.00 , 0.00)
	800	0.06	(0.03 , 0.11)	0.01	(0.00 , 0.02)	0.00	(0.00 , 0.00)
	1500	0 09	(0.06 , 0.14)	0.02	(0.01 , 0.04)	0.00	(0.00 , 0.01)
	3000	0.14	(0.10 , 0.19)	0.03	(0.02 , 0.06)	0.01	(0.00 , 0.02)
	5000	0 18	(0.13 , 0.24)	0.05	(0.03 , 0.08)	0.01	(0.00 , 0.03)
	10000	0.25	(0.19 , 0.31)	0.07	(0.05 , 0.12)	0.02	(0.01 , 0.04)
	20000	0.32	(0.25 , 0.41)	0.11	(0.07 , 0.17)	0.04	(0.02 , 0.07)

Results are based on a time adjusted analysis held fixed at October 13, which was the median sampling date.

7.0 PARTIAL SIGNIFICANCE OF WINDOW WELL PB MEASUREMENTS

The final analysis performed was used to determine whether the predictive ability of the model improves when adding window well lead levels to a model which already accounts for dust lead on floors and window sills. The analysis begins with a base model which adjusts for temporal variations in blood-lead concentrations, and then sequentially adds variables representing lead in floors, window sills, and window wells to the model. The results of this analysis are reported in Table 4. The slope parameters and associated 95% confidence intervals in each row correspond to a statistical model which includes the variables in the base model and the variable being added to the base model. The coefficient of determination (R^2) is provided for each model fitted, where floors, sills and wells are added sequentially to the base model. The difference in R^2 values between the full model and the base model is also presented. This value corresponds to the extra amount of variability explained by the variable being added to the model.

The estimated effect of BRM well lead on blood lead was only marginally statistically significant after adjusting for the effects of floor lead, sill lead, and temporal variation. Floor lead appeared to explain most of the variability in blood lead for both BRM and wipe lead loading, but was less predictive for BRM lead concentration. The model with only BRM floor lead loading and an adjustment for temporal trends explained 16.2% of the variability in blood-lead concentrations, adding window sill lead loading to the model explained an additional 4.4% of the variability, and adding window well lead loading with the other two factors already in the model explained an additional 5.4% of the variability. The amount of extra variability explained by window sill-lead loading after already accounting for floor-dust lead loading and temporal variations is calculated by subtracting the coefficient of determination from the base model (R^2=0.162)

Table 4. Results of Fitting Floor, Window Sill, and Window Well Lead Loadings or Concentrations Simultaneously on Blood-Lead Concentrations Based on the Least Squares Approach

Unit of Measure	Sample Size	Variables in the Base Model	Variables Added to the Base Model	Slope Values			R^2 for the Full Model	Additional Variability Explained
				β1 (Floors) (95% CI)	β1 (Sills) (95% CI)	β1 (Wells) (95% CI)		
Slope Values in Units of ln(μg Pb / dL Blood) / ln(μg Pb / ft² Sampled) (Dust Samples Collected with BRM Sampler)								
Loading (μg/ft²) BRM Sampler	177	Date	Floors	0 120 (0 077 , 0 162)			0.162	0.148
		Date, Floors	Window Sills	0 090 (0.044 , 0 135)	0.063 (0.023 , 0.103)		0.206	0 044
		Date, Floors	Window Wells	0 092 (0.051 , 0 134)		0 066 (0 039 , 0.094)	0.256	0 094
		Date, Floors, Window Sills	Window Wells	0.085 (0.041 , 0.129)	0 023 (-0.022, 0 068)	0.058 (0.026 , 0.090)	0.260	0.054 (W) 0.004 (S)
Slope Values in Units of ln(μg Pb / dL Blood) / ln(μg Pb / ft² Sampled) (Dust Samples Collected with Wipe Samples)								
Loading (μg/ft²) Wipe Samples	178	Date	Floors	0.190 (0.112 , 0.267)			0.123	0.112
		Date, Floors	Window Sills	0 138 (0.054 , 0 222)	0.105 (0.038 , 0.172)		0 168	0.045
		Date, Floors	Window Wells	0.140 (0.057 , 0.223)		0 062 (0 023 , 0.101)	0.168	0.045
		Date, Floors, Window Sills	Window Wells	0.125 (0.040 , 0.210)	0.067 (-0.013, 0.147)	0.040 (-0.007 , 0.087)	0.181	0.013 (W) 0 013 (S)
Slope Values in Units of ln(μg Pb / dL Blood) / ln(μg Pb / g Dust) (Dust Samples Collected with BRM Sampler)								
Concentration (μg/g) BRM Sampler	175	Date	Floors	0.070 (0.013 , 0.127)			0.047	0.032
		Date, Floors	Window Sills	0.043 (-0.014, 0 100)	0 076 (0.030 , 0.122)		0.102	0.055
		Date, Floors	Window Wells	0.054 (-0.003, 0.111)		0.052 (0.013 , 0.091)	0.083	0.036
		Date, Floors, Window Sills	Window Wells	0.041 (-0 017, 0.098)	0.060 (0.006 , 0.114)	0.026 (-0.019, 0 071)	0.108	0 006 (W) 0.025 (S)

* The reported values of the coefficient of determination (R^2) are based on a least squares fit of the descriptive model without adjusting for the errors in predictor variables.

(w) Represents the addition variability explained by window wells when it is the last variable added to the model.

(s) Represents the additional variability explained by window sills when it is the last variable added to the model.

from the coefficient of determination from the full model (R^2=0.206) and then multiplying by 100. The model with only BRM floor lead concentration and an adjustment for seasonal trends explained 4.7% of the variability in blood-lead concentrations, adding window sill lead concentration to the model explained an additional 5.5% of the variability, and adding window well lead concentration with the other two factors already in the model explained an additional 0.6% of the variability.

The predictive ability of the model did not improve significantly when measures of window well dust-lead levels were added to a model which already accounted for dust lead on floors and window sills. The predictive ability of a regression model will not improve significantly when the variable added to the model is highly correlated with another predictor variable. Therefore, one possible explanation for the results seen in Table 4 is that dust lead measurements from floors, window sills, and window wells within a house are correlated. Table 5 demonstrates estimated Pearson correlation coefficients among natural log transformed lead levels from children's blood and floor, window sill and window well dust. These tables demonstrate that for each measurement method (BRM Loading, Wipe Loading, BRM Concentration), lead levels from window sills and window wells are statistically significantly correlated with each other, and with children's blood-lead concentrations. In addition, the correlations between window sills and wells are consistently the highest concentrations shown in Table 5.

Table 5. Estimated Pearson Correlation Coefficients Between Natural Log Transformed Lead Levels from Children's Blood and Floor, Window Sill and Window Well Dust

		Floors	Window Sills	Window Wells
		Lead Loadings (BRM Sampler)		
Blood	ρ p-value n	0.344 0.001 193	0.343 <0.001 197	0.374 <0.001 189
Floors	ρ p-value n	1	0.411 <0.001 189	0.271 0.001 179
Window Sills	ρ p-value n		1	0.558 <0.001 184
		Lead Loadings (Wipe Samples)		
Blood	ρ p-value n	0.310 <0.001 197	0.338 <0.001 196	0.305 <0.001 189
Floors	ρ p-value n	1	0.395 <0.001 189	0.365 <0.001 182
Window Sills	ρ p-value n		1	0.627 <0.001 184
		Lead Concentration (BRM Sampler)		
Blood	ρ p-value n	0.125 0.084 192	0.236 <0.001 199	0.211 0.004 188
Floors	ρ p-value n	1	0.325 0.047 189	0.225 0.003 177
Window Sills	ρ p-value n		1	0.552 <0.001 183

APPENDIX A
STATISTICAL MODELS

The Statistical Model

The statistical model fitted to the data in the main report was descriptive in nature and appears as follows:

$$\log(PbB_i) = \beta_0 + \beta_1 \log(PbE_i) + \beta_2 (t_i - \theta) + E_i \qquad (1)$$

where PbB_i is the blood-lead level in µg/dL for the ith child, PbE_i is the environmental-lead level for the ith home in µg/ft^2 for loadings and µg/g for concentrations, t_i is the day of the year on which the PbB_i measurement was taken, and E_i is the random error term associated with PbB_i. E_i is assumed to follow a normal distribution with mean zero and standard deviation σ_{Error}. PbE can represent either a lead loading or lead concentration in floor, sill, or well dust.

β_0, β_1, β_2 and σ_{Error} are parameters that are estimated when the model is fitted. β_0 and β_1 are the intercept and slope of the assumed log-linear relationship between PbB and PbE. Since the dates of environmental sampling range from August 31, 1993 through November 20, 1993 there was not enough of a range of sample dates to properly parameterize a sine wave model for seasonal variations in blood-lead. Therefore, a simple linear trend was fitted between August 31 and November 20, where β_2 is the slope and θ is the mean date of sampling (October 13, 1993). σ_{Error} characterizes the variability in blood-lead left unexplained by the model.

Errors in Variables Solution

Parameter estimates from a least squares regression model for variables that are measured with error are usually biased towards zero. Appendix B provides details on the statistical methodology used to correct the parameter estimates to reduce this bias, and Appendix D details how measurement error in composite dust lead measurements was estimated for use in these adjusted models.

Tables E1 and E2 in Appendix E provide the parameter estimates and associated standard errors for the intercept and slope (β_0 and β_1) from the descriptive model as estimated by both ordinary least squares and the errors in variables statistical approach. The errors in variables solution assumes that the measurement error in dust samples is known, and fixed at the values presented in Appendix D. The ordinary least squares solution assumes that there is no measurement error in the dust lead variables (i.e. $\sigma_{Loading}$ $\sigma_{Concentration}$ = 0).

A comparison of the slope parameter for dust lead (β_1) between the least squares and errors in variables solution demonstrates that for variables that have a strong relationship with blood-lead (such as floor wipe lead loading), the bias in β_1 attributable to measurement error can be substantial. However, when the relationship between the predictor variable and the response variable is weak (such as floor-lead concentration) the bias in β_1 attributable to measurement error is not as large.

To facilitate a comparison between the assumed known measurement error and zero measurement error, all statistical results are presented in the Appendices for both the least squares and the errors in variables solution.

Alternate Statistical Models

The descriptive model presented in the main body of the report makes a simplifying assumption about the data from the Rochester Lead in Dust Study. The model, as fitted, does not account for the effects of potentially important socioeconomic and behavioral factors. Investigators in the Rochester Lead-in-Dust Study found that four covariates in particular were "significantly associated with higher blood lead levels in children: Black Race, parental reports that children put soil in their mouths, single parent household, and higher ferritin level".[2]

No attempts have been made at this time to investigate changes in the relationship between blood-lead concentration and measures of lead in dust that would be caused by the presence of these important covariates in the log-linear regression models.

[2]Department of Pediatrics, Biostatistics, and Environmental Medicine, The University of Rochester School of Medicine, (June, 1995), "The Relation of Lead Contaminated House Dust and Blood Lead Leveles Among Urban Children, Final Report, Volume II, Results and Discussion", U.S. Department of Housing and Urban Development Grant No. MLDP T0001-93

APPENDIX B

ALTERNATIVE REGRESSION PARAMETER ESTIMATION IN THE PRESENCE OF MEASUREMENT ERROR

Appendix B

Regression Parameter Estimation in the Presence of Measurement Error

Let

$$Y = X\beta + \epsilon \tag{1}$$

where

Y = a nx1 vector containing the n values of the dependent variable;

X = a nxp matrix where each column contains the n values of one independent variable in the regression model (in a model with an intercept term, one of the columns would be a column of ones);

β = a px1 vector of regression coefficients; and

ϵ = a nx1 vector of random error terms.

In a standard regression model it is assumed that X is a matrix of fixed and known constants, β is a vector of fixed and unknown constants, and ϵ is distributed as $MVN(0,\sigma^2 I)$ where $MVN(\mu,\Sigma)$ represents a multivariate normal distribution with mean vector μ and covariance matrix Σ. Estimates of regression parameters for this standard regression model are obtained as follows:

$$\hat{\beta} = (X'X)^{-1} X'Y$$

$$\hat{\sigma}^2 = (Y'Y - \hat{\beta}_1'X'X\hat{\beta}_1) / (n-p) \tag{2}$$

$$C\hat{o}v(\hat{\beta}_1) = \hat{\sigma}^2 (X'X)^{-1}$$

In the presence of measurement error, it is assumed that

$$Y = U\beta + \epsilon \tag{3}$$

where

U = a nxp matrix of fixed but unknown constants representing the values of the independent variables if measured without error;

X = U + Δ, and

Δ = a nxp matrix of the random measurement errors associated with each of the observed values of the independent variables.

Y and ϵ are as defined above. It is assumed that Δ is distributed as $MVN(0, \Sigma_\Delta)$ where Σ_Δ is known and Δ is stochastically independent of ϵ. Under this measurement error model, estimates of regression parameters are obtained as follows:

$$\hat{\beta} = (X'X - n\Sigma_\Delta)^{-1} X'Y$$

$$\hat{\sigma}^2 = (Y'Y - \hat{\beta}'(X'X - (n-p)\Sigma_\Delta)\hat{\beta}) / (n-p) \tag{4}$$

$$C(\hat{\beta}) = \hat{\sigma}^2 (X'X - n\Sigma_\Delta)^{-1}$$

These estimators are equivalent to those recommended in Equations (2.2.11) and (2.2.12) by Fuller (Measurement Error Models, 1987).

It can be shown that

(1a) The difference between $[(X'X - n\Sigma_\Delta) / n]$ and $[U'U / n]$ converges in probability to zero as $n \to \infty$;

(1b) The difference between $[(X'X - (n-p)\Sigma_\Delta) / (n-p)]$ and $[U'U / (n-p)]$ converges in probability to zero as $n \to \infty$; and

(2) The difference between $[X'Y / n]$ and $[U'Y / n]$ converges in probability to zero as $n \to \infty$.

Using these facts, it follows that the differences between the regression parameter estimates of Equation (4) and

$$\hat{\beta} = (U'U)^{-1} U'Y$$

$$\hat{\sigma}^2 = (Y'Y - \hat{\beta}' U'U \hat{\beta}) / (n-p) \qquad (5)$$

$$C\hat{o}(\hat{\beta}) = \hat{\sigma}^2 (U'U)^{-1}$$

converge in probability to zero as $n \to \infty$.

Note that the estimators in Equation (5) are equivalent to those of Equation (2) except that X has been replaced by U. Thus, if U were known, the estimators of Equation (5) would be used. However, since U is unknown, the asymptotically equivalent estimators of Equation (4) are used. For the purpose of making inferences involving the unknown parameters β and σ^2, it is assumed that the estimators of Equation (4) have the same distribution as those of Equation (5).

In this application of obtaining regression parameter estimates in the presence of measurement error, the covariate represents a weighted average of several observed dust-lead levels that are measured with error. Therefore, the estimate of measurement error in an individual sample obtained from Appendix D must be divided by the number of individual samples that were used to construct the dust-lead variable being used in the regression model. Thus each diagonal entry of Σ_Δ ($\sigma_{\Delta(ii)}$) becomes the estimate of measurement error from Appendix D divided by the number of individual dust samples (of a given component type) that were collected from the ith house.

APPENDIX C

TOLERANCE BOUNDS AND CONFIDENCE INTERVALS FOR PERCENTILES AND EXCEEDANCE PROBABILITIES IN A REGRESSION SETTING

Appendix C

Tolerance Bounds and Confidence Intervals for Percentiles and Exceedance Probabilities in a Regression Setting

Assume the standard regression model of Equation (1) of Appendix B. Estimates of regression parameters are obtained as follows:

$$\hat{\beta} = (X'X)^{-1} X'Y \tag{1}$$

$$\hat{\sigma}^2 = (Y'Y - \hat{\beta}'X'X\hat{\beta}) / (n-p)$$

A 95% upper tolerance bound on (1-q)% of the distribution of Y for values of the independent variables given by x_0 is

$$T_U = x_0'\hat{\beta} + k\hat{\sigma} \tag{2}$$

where

$$k = L^{1/2}\, t_{0.95,n-p}[\Phi^{-1}(1-q) / L^{1/2}], \tag{3}$$

$L = x_0'(X'X)^{-1}x_0$ is the leverage of the vector x_0, and $t_{\alpha,\nu}[\delta]$ is the αth percentile of the noncentral t distribution with ν degrees of freedom and noncentrality parameter δ. Similarly, a 95% confidence interval for the (1-q)th percentile of the distribution of Y for values of the independent variables given by x_0 is given by

$$(T_L, T_U) \tag{4}$$

where

$$T_L = x_0' \hat{\beta} + k_L \hat{\sigma}$$

$$T_U = x_0' \hat{\beta} + k_U \hat{\sigma} \qquad (5)$$

$$k_L = L^{1/2}\ t_{0.025,n-p}[\Phi^{-1}(1-q)\ /\ L^{1/2}]$$
$$k_U = L^{1/2}\ t_{0.975,n-p}[\Phi^{-1}(1-q)\ /\ L^{1/2}]$$

A 95% confidence interval for q_y = Prob(Y>y) is

$$(q_L,\ q_U) \qquad (6)$$

where q_L is the value of q for which T_L=y and q_U is the value of q for which T_U=y.

Under the measurement error model of Equation (3) of Appendix B, Equations (2) through (6) above still apply. However, under this measurement error model, values of β^, σ^, and L should be calculated as follows:

$$\hat{\beta} = (X'X - n\Sigma_\Delta)^{-1}\ X'Y$$

$$\hat{\sigma}^2 = (Y'Y - \hat{\beta}\ '(X'X - (n-p)\Sigma_\Delta)\ \hat{\beta}\ )\ /\ (n-p)$$

$$L = x_0'(X'X - n\Sigma_\Delta)^{-1}x_0$$

APPENDIX D

ESTIMATION OF MEASUREMENT ERROR VARIANCE COMPONENTS

APPENDIX D

Details on Measurement Error Estimation

The statistical models which adjust for measurement error in predictor variables assume that the variability due to sampling and chemical analysis of dust samples is fixed and known. Several sources of data were considered for providing information about the variability in dust sample results due to measurement error including information from the Rochester Lead-in-Dust Study, the R&M study, data from the Lead Abatement Effectiveness Study in Milwaukee, and data from the Comprehensive Abatement Performance Study (CAPS). These data represent side-by-side field duplicate vacuum dust samples from floors, and can be evaluated using the following variance components model:

$$\ln(\text{Dust}_{ij}) = \ln(\mu) + P_i + E_{ij}$$

where Dust_{ij} is the jth (first or second) lead-loading or lead-concentration result from the ith side-by-side sample, μ is the geometric mean of Dust_{ij} among all side-by-side pairs, P_i is the random effect associated with the ith side-by-side pair, and E_{ij} is the random within-pair error term associated with Dust_{ij}. P_i is assumed to follow a normal distribution with mean zero and variance $\sigma^2_{\text{Between}}$, and E_{ij} is assumed to follow a normal distribution with mean zero and variance σ^2_{Error}.

$\sigma^2_{\text{Between}}$ characterizes the variability between pairs, and σ^2_{Error} characterizes the variability attributed to measurement error in each source of data. Table D1 provides estimates of σ^2_{Error} found from each source of data.

Estimates of variability in Side-by-Side dust sample results from the Rochester Lead-in-Dust Study were used in the statistical models which account for measurement error in predictor variables. These values were chosen to promote internal consistency within the data being analyzed.

Table D1. Estimates of Variability In Side-by-Side Dust Sample Results Attributable to Measurement Error.

Data Source	Sampling Method	Component Type	Measure	σ_{Error} (ln Std Dev)	Number of Pairs
Rochester Lead-in-Dust Study	BRM	Floors	Loading	1.107	22
			Concentration	1.382	22
		Window Sills	Loading	1.494	15
			Concentration	1.745	14
		Window Wells	Loading	2.872	14
			Concentration	2.201	14
	Wipe	Floors	Loading	0.764	22
		Window Sills	Loading	0.801	16
		Window Wells	Loading	2.383	15
Milwaukee	BRM	Kitchen Floor	Loading	1.022	42
			Concentration	1.151	
Repair and Maintentance	BRM	Interior Entryways	Loading	1.279	12
			Concentration	0.624	
CAPS	Wipe	Floors	Loading	0.56	35

APPENDIX E

PARAMETER ESTIMATES FOR STATISTICAL MODELS

Table E1. Results of Fitting Statistical Models to BRM Lead-Loading Data from the Rochester Lead-in-Dust Study

Statistical Approach	Component Tested	Parameter Estimates for Dust		Parameter Estimate for Time Effect	Estimate of Error Variance
		β_0[(a)] se(β_0)	β_1[(b)] se(β_1)	β_2[(c)] se(β_2)	$[\ln(\mu g/dL)]^2$
Least Squares	Floors	1.540 (0.072)	0.109 (0.020)	-0.004 (0.002)	0.332
	Window Sills	1.290 (0.111)	0.095 (0.018)	-0.004 (0.002)	0.332
	Window Wells	1.064 (0.143)	0.077 (0.014)	-0.004 (0.002)	0.330
Errors in Variables	Floors	1.471 (0.076)	0.133 (0.022)	-0.004 (0.002)	0.322
	Window Sills	1.108 (0.123)	0.126 (0.020)	-0.005 (0.002)	0.316
	Window Wells	0.345 (0.179)	0.149 (0.017)	-0.005 (0.002)	0.279

(a) Intercept values reported in units of ln(μg Pb/dL Blood).

(b) Slope values reported in units of ln(μg Pb/dL Blood) / ln(μg Pb/ft^2 sampled).

(c) Time effect reported in units of $\frac{\ln(\mu g/dL)}{\text{date - 10/13/93}}$.

Table E2. Results of Fitting Statistical Models to Wipe Lead-Loading Data from the Rochester Lead-in-Dust Study

Statistical Approach	Component Tested	Parameter Estimates for Dust		Parameter Estimate for Time Effect	Estimate of Error Variance
		β_0[(a)] se(β_0)	β_1[(b)] se(β_1)	β_2[(c)] se(β_2)	$[\ln(\mu g/dL)]^2$
Least Squares	Floors	1.367 (0.113)	0.172 (0.036)	-0.004 (0.002)	0.339
	Window Sills	1.014 (0.165)	0.157 (0.030)	-0.004 (0.002)	0.336
	Window Wells	1.162 (0.159)	0.080 (0.018)	-0.004 (0.002)	0.349
Errors in Variables	Floors	1.179 (0.127)	0.237 (0.042)	-0.004 (0.002)	0.325
	Window Sills	0.797 (0.181)	0.198 (0.033)	-0.004 (0.002)	0.324
	Window Wells	0.328 (0.218)	0.179 (0.025)	-0.004 (0.002)	0.306

(a) Intercept values reported in units of ln(μg Pb/dL Blood).

(b) Slope values reported in units of ln(μg Pb/dL Blood) / ln(μg Pb/ft^2 sampled).

(c) Time effect reported in units of $\frac{\ln(\mu g/dL)}{\text{date - 10/13/93}}$.

Table E3. Results of Fitting Statistical Models to BRM Lead-Concentration Data from the Rochester Lead-in-Dust Study

Statistical Approach	Component Tested	Parameter Estimates for Dust		Parameter Estimate for Time Effect	Estimate of Error Variance $[\ln(\mu g/dL)]^2$
		β_0[(a)] $se(\beta_0)$	β_1[(b)] $se(\beta_1)$	β_2[(c)] $se(\beta_2)$	
Least Squares	Floors	1.493 (0.178)	0.058 (0.027)	-0.004 (0.002)	0.376
	Window Sills	1.215 (0.167)	0.080 (0.020)	-0.005 (0.002)	0.352
	Window Wells	1.301 (0.177)	0.060 (0.019)	-0.004 (0.002)	0.370
Errors in Variables	Floors	1.201 (0.233)	0.104 (0.036)	-0.005 (0.002)	0.369
	Window Sills	0.854 (0.202)	0.126 (0.025)	-0.006 (0.002)	0.337
	Window Wells	0.832 (0.232)	0.111 (0.025)	-0.005 (0.002)	0.353

(a) Intercept values reported in units of ln(μg Pb/dL Blood).

(b) Slope values reported in units of ln(μg Pb/dL Blood) / ln(μg Pb/g Dust).

(c) Time effect reported in units of $\frac{\ln(\mu g/dL)}{\text{date} - 10/13/93}$.

Table E4. Results of Fitting Floor, Window Sill, and Window Well Lead Loadings (BRM Sampler) Simultaneously on Blood-Lead Concentrations for the Rochester Lead-in-Dust Study.

Statistical Approach	Component Tested	Parameter Estimates for Dust		Parameter Estimate for Time Effect β_2[(c)] se(β_2)	Estimate of Error Variance $[\ln(\mu g/dL)]^2$
		β_0[(a)] se(β_0)	β_1[(b)] se(β_1)		
Least Squares	Floors	0.876 (0.148)	0.085 (0.022)	-0.005 (0.002)	0.300
	Window Sills		0.023 (0.023)		
	Window Wells		0.058 (0.016)		
Errors in Variables	Floors	-0.226 (0.197)	0.125 (0.024)	-0.004 (0.002)	0.233
	Window Sills		-0.219 (0.043)		
	Window Wells		0.297 (0.037)		

(a) Intercept values reported in units of ln(μg Pb/dL Blood).

(b) Slope values reported in units of ln(μg Pb/dL Blood) / ln(μg Pb/ft^2 sampled).

(c) Time effect reported in units of $\frac{\ln(\mu g/dL)}{\text{date - 10/13/93}}$.

Table E5. Results of Fitting Floor, Window Sill, and Window Well Lead Loadings (Wipe Samples) Simultaneously on Blood-Lead Concentrations for the Rochester Lead-in-Dust Study.

Statistical Approach	Component Tested	Parameter Estimates for Dust		Parameter Estimate for Time Effect β_2[(c)] se(β_2)	Estimate of Error Variance $[\ln(\mu g/dL)]^2$
		β_0[(a)] se(β_0)	β_1[(b)] se(β_1)		
Least Squares	Floors	0.790 (0.188)	0.125 (0.043)	-0.004 (0.002)	0.330
	Window Sills		0.067 (0.041)		
	Window Wells		0.040 (0.024)		
Errors in Variables	Floors	(d)			
	Window Sills				
	Window Wells				

(a) Intercept values reported in units of ln(μg Pb/dL Blood).

(b) Slope values reported in units of ln(μg Pb/dL Blood) / ln(μg Pb/ft^2 sampled).

(c) Time effect reported in units of $\frac{\ln(\mu g/dL)}{\text{date} - 10/13/93}$.

(d) The simultaneous fitting of dust-lead from floors, window sills and window wells was conducted on a subset of the data which had non-missing values for all three variables. The variability of the observed dust-lead loadings from window sills and window wells in this restricted subset of the data was less than the estimate of variability attributed to measurement error that was being used as input to the errors in variables regression models. Attempts to compute the errors in variables solution under these circumstances resulted in nonsensical parameter estimates with associated negative variances. Therefore, it was inappropriate to provide these parameter estimates for the errors in variables solution to the simultaneous fitting of wipe dust-lead loadings from floors, window sills and window wells.

Table E6 Results of Fitting Floor, Window Sill, and Window Well Lead Concentrations (BRM Sampler) Simultaneously on Blood-Lead Concentrations for the Rochester Lead-in-Dust Study.

Statistical Approach	Component Tested	Parameter Estimates for Dust		Parameter Estimate for Time Effect β_2[c] $se(\beta_2)$	Estimate of Error Variance $[\ln(\mu g/dL)]^2$
		β_0[a] $se(\beta_0)$	β_1[b] $se(\beta_1)$		
Least Squares	Floors	0.870 (0.244)	0.041 (0.030)	-0.006 (0.002)	0.365
	Window Sills		0.060 (0.028)		
	Window Wells		0.026 (0.023)		
Errors in Variables	Floors	0.617 (0.289)	0.048 (0.043)	-0.008 (0.002)	0.352
	Window Sills		0.152 (0.080)		
	Window Wells		-0.032 (0.070)		

(a) Intercept values reported in units of ln(μg Pb/dL Blood).

(b) Slope values reported in units of ln(μg Pb/dL Blood) / ln(μg Pb/g Dust).

(c) Time effect reported in units of $\frac{\ln(\mu g/dL)}{\text{date - 10/13/93}}$.

APPENDIX F

PROTECTIVE DUST LEAD LEVELS AND EXCEEDANCE PROBABILITIES FOR ERRORS IN VARIABLES SOLUTION

Table F1. Estimated Dust Pb Loadings for Floors, Window Sills, and Window Wells at Which the 85th, 90th, 95th and 99th Percentiles of Childhood Blood Pb Concentrations Reach 10, 15, and 20 μg/dL (Based on the Errors in Variables Regression Models of the Rochester Lead-in-Dust Study Data)

Sample Type	Tolerance Level	Target Blood-Lead Concentration		
		10 μg/dL	15 μg/dL	20 μg/dL
Floor Pb Loading (μg/ft²) BRM Sampler	0.85	4	88	553
	0.90	1	32	223
	0.95	Out of Range	5	52
	0.99	Out of Range	Out of Range	1
Window Sill Pb Loading (μg/ft²) BRM Sampler	0.85	89	2,209	15,477
	0.90	23	770	5,938
	0.95	2	133	1,307
	0.99	Out of Range	2	45
Window Well Pb Loading (μg/ft²) BRM Sampler	0.85	10,156	144,436	805,938
	0.90	3,779	61,592	362,045
	0.95	817	15,940	104,728
	0.99	41	982	8,045
Floor Pb Loading (μg/ft²) Wipe Samples	0.85	7	40	112
	0.90	3	23	67
	0.95	Out of Range	8	30
	0.99	Out of Range	Out of Range	4
Window Sill Pb Loading (μg/ft²) Wipe Samples	0.85	74	578	1,965
	0.90	30	294	1,068
	0.95	7	93	405
	0.99	Out of Range	7	45
Window Well Pb Loading (μg/ft²) Wipe Samples	0.85	1,799	16,621	66,800
	0.90	732	7,989	33,992
	0.95	179	2,420	11,785
	0.99	11	190	1,208

Table F2. Estimated Dust Pb Concentrations for Floors, Window Sills, and Window Wells at Which the 85th, 90th, 95th and 99th Percentiles of Childhood Blood Pb Concentrations Reach 10, 15, and 20 μg/dL (Based on the Errors in Variables Regression Models of the Rochester Lead-in-Dust Study Data)

Sample Type	Tolerance Level	Target Blood-Lead Concentration		
		10 μg/dL	15 μg/dL	20 μg/dL
Floor Pb Concentration (μg/g) BRM Sampler	0.85	14	2,450	16,581
	0.90	Out of Range	685	6,088
	0.95	Out of Range	23	1,106
	0.99	Out of Range	Out of Range	1
Window Sill Pb Concentration (μg/g) BRM Sampler	0.85	593	16,270	104,638
	0.90	125	5,586	40,827
	0.95	11	830	8,974
	0.99	Out of Range	10	228
Window Well Pb Concentration (μg/g) BRM Sampler	0.85	1,104	49,044	378,000
	0.90	162	14,463	131,306
	0.95	8	1,488	23,482
	0.99	Out of Range	6	280

Table F3. Estimated Proportion of Children with Blood Pb Concentrations Greater than 10, 15, and 20 μg/dL as Predicted by Errors in Variables Regression Models of Blood Pb versus BRM Lead Loadings from Floors, Window Sills and Wells

Surface Tested	Pb Loading $\mu g/ft^2$	Proportion Greater Than 10 μg/dl		Proportion Greater Than 15 μg/dl		Proportion Greater Than 20 μg/dl	
		Pr(Pb>10)	95% CI	Pr(Pb>15)	95% CI	Pr(Pb>20)	95% CI
Floors	5	0.11	(0.07 , 0.16)	0.02	(0.01 , 0.05)	0.00	(0.00 , 0.01)
	10	0.15	(0 10 , 0.20)	0.04	(0.02 , 0.06)	0.01	(0.00 , 0.02)
	15	0.17	(0.12 , 0.22)	0.04	(0.02 , 0.07)	0.01	(0.00 , 0.02)
	20	0.19	(0.14 , 0.24)	0.05	(0 03 , 0.08)	0.01	(0.00 , 0 03)
	25	0.20	(0.15 , 0.26)	0.06	(0.03 , 0.09)	0.02	(0.01 , 0.03)
	30	0.21	(0.16 , 0.27)	0 06	(0.04 , 0.10)	0.02	(0.01 , 0.04)
	35	0.22	(0.17 , 0.29)	0.07	(0 04 , 0.10)	0.02	(0.01 , 0.04)
	40	0.23	(0.18 , 0.30)	0.07	(0.04 , 0.11)	0.02	(0.01 , 0.04)
	100	0.31	(0.24 , 0.38)	0.11	(0 07 , 0.16)	0.04	(0.02 , 0.07)
	200	0.37	(0.28 , 0.46)	0.14	(0 09 , 0.21)	0.06	(0.03 , 0.10)
	250	0.39	(0.29 , 0 49)	0 16	(0.10 , 0.23)	0 06	(0.03 , 0.11)
Window Sills	50	0 08	(0.05 , 0 13)	0.01	(0.00 , 0.03)	0.00	(0.00 , 0 01)
	100	0 11	(0 07 , 0.16)	0 02	(0.01 , 0.04)	0.00	(0.00 , 0.01)
	200	0.14	(0.10 , 0.19)	0.03	(0.02 , 0.06)	0.01	(0 00 , 0.02)
	300	0.16	(0.12 , 0.22)	0.04	(0 02 , 0.07)	0.01	(0.00 , 0.02)
	400	0.18	(0.13 , 0.23)	0.05	(0.03 , 0.08)	0.01	(0.00 , 0.03)
	500	0.19	(0.14 , 0.25)	0 05	(0.03 , 0.09)	0 01	(0.00 , 0.03)
	600	0.20	(0 15 , 0.26)	0 06	(0.03 , 0.09)	0.02	(0.01 , 0.03)
	700	0 21	(0.16 , 0.27)	0.06	(0.04 , 0.10)	0 02	(0.01 , 0.04)
Window Wells	200	0.00	(0 00 , 0.02)	0.00	(0.00 , 0.00)	0.00	(0.00, 0.00)
	500	0.01	(0 00 , 0 04)	0.00	(0 00 , 0 00)	0.00	(0.00 , 0.00)
	750	0.02	(0.01 , 0.05)	0 00	(0 00 , 0.00)	0.00	(0.00 , 0.00)
	800	0.02	(0.01 , 0.05)	0 00	(0.00 , 0.01)	0.00	(0.00 , 0.00)
	1500	0 03	(0.01 , 0 07)	0 00	(0.00 , 0.01)	0.00	(0.00 , 0.00)
	3000	0 05	(0.03 , 0.09)	0.00	(0.00 , 0.02)	0.00	(0.00 , 0.00)
	5000	0.07	(0.04 , 0.12)	0.01	(0.00 , 0.02)	0.00	(0 00 , 0.00)
	10000	0 10	(0.07 , 0.15)	0.02	(0.01 , 0.04)	0.00	(0.00 , 0 01)
	20000	0 15	(0.10 , 0.20)	0.03	(0.02 , 0.06)	0.00	(0.00 , 0.02)

Table F4. Estimated Proportion of Children with Blood Pb Concentrations Greater than 10, 15, and 20 µg/dL as Predicted by Errors in Variables Regression Models of Blood Pb versus Wipe Lead Loadings from Floors, Window Sills and Wells

Surface Tested	Pb Loading µg/ft²	Proportion Greater Than 10 µg/dl		Proportion Greater Than 15 µg/dl		Proportion Greater Than 20 µg/dl	
		Pr(Pb>10)	95% CI	Pr(Pb>15)	95% CI	Pr(Pb>20)	95% CI
Floors	5	0.08	(0.04 , 0.13)	0.01	(0.00 , 0.03)	0.00	(0.00 , 0.01)
	10	0.13	(0.09 , 0.18)	0.03	(0.01 , 0.06)	0.01	(0.00 , 0.02)
	15	0.17	(0.12 , 0.22)	0.04	(0.02 , 0.07)	0.01	(0.00 , 0.03)
	20	0.20	(0.15 , 0.26)	0.06	(0.03 , 0.09)	0.02	(0.01 , 0.03)
	25	0.23	(0.18 , 0.29)	0.07	(0.04 , 0.11)	0.02	(0.01 , 0 04)
	30	0.25	(0.20 , 0.32)	0.08	(0.05 , 0.12)	0.03	(0.01 , 0.05)
	35	0.27	(0.21 , 0.34)	0.09	(0.06 , 0.14)	0.03	(0.01 , 0.06)
	40	0.29	(0.23 , 0.37)	0.1	(0.06 , 0.15)	0.04	(0.02 , 0.06)
	100	0.44	(0.32 , 0.55)	0.19	(0.12 , 0.28)	0.08	(0.04 , 0.14)
	200	0.55	(0.40 , 0.69)	0.28	(0.16 , 0.42)	0.14	(0.07 , 0.24)
	250	0.59	(0.42 , 0.73)	0.31	(0.18 , 0.47)	0.16	(0.08 , 0 28)
Window Sills	50	0.08	(0.04 , 0.13)	0.01	(0.00 , 0.03)	0.00	(0.00 , 0.01)
	100	0.12	(0.08 , 0.18)	0.03	(0.01 , 0.05)	0.00	(0.00 , 0.02)
	200	0 18	(0.13 , 0.24)	0.05	(0.03 , 0.08)	0.01	(0.00 , 0.03)
	300	0.22	(0.17 , 0.28)	0.07	(0.04 , 0.10)	0.02	(0.01 , 0.04)
	400	0.25	(0.19 , 0.32)	0.08	(0.05 , 0.12)	0.03	(0.01 , 0.05)
	500	0.28	(0.21 , 0.35)	0.09	(0.06 , 0.14)	0.03	(0.01 , 0.06)
	600	0.30	(0.23 , 0.38)	0.11	(0.07 , 0.16)	0.04	(0.02 , 0.07)
	700	0 32	(0.24 , 0.40)	0.12	(0.07 , 0.17)	0.04	(0 02 , 0.08)
Window Wells	200	0.02	(0 00 , 0.05)	0.00	(0.00 , 0.01)	0.00	(0.00 , 0.00)
	500	0.05	(0.02 , 0.09)	0.00	(0 00 , 0.02)	0.00	(0.00 , 0.00)
	750	0 06	(0.03 , 0.10)	0.01	(0.00 , 0.02)	0.00	(0.00 , 0.00)
	800	0.06	(0 03 , 0 11)	0 01	(0.00 , 0.02)	0.00	(0.00 , 0 00)
	1500	0.09	(0.06 , 0.14)	0.02	(0.01 , 0.04)	0.00	(0 00 , 0.01)
	3000	0.14	(0.10 , 0.19)	0.03	(0.02 , 0 06)	0.01	(0.00 , 0.02)
	5000	0 18	(0.13 , 0 24)	0.05	(0.03 , 0.08)	0.01	(0.00 , 0.03)
	10000	0.25	(0.19 , 0 31)	0 07	(0.05 , 0.12)	0.02	(0.01 , 0 04)
	20000	0 32	(0.25 , 0 41)	0 11	(0.07 , 0.17)	0.04	(0.02 , 0.07)

APPENDIX G

PROTECTIVE DUST LEAD LEVELS AND EXCEEDANCE PROBABILITIES FOR LEAST SQUARES SOLUTION

Table G1. Estimated Dust Pb Loadings for Floors, Window Sills, and Window Wells at Which the 85th, 90th, 95th and 99th Percentiles of Childhood Blood Pb Concentrations Reach 10, 15, and 20 μg/dL (Based on the Least Squares Regression Models of the Rochester Lead-in-Dust Study Data)

Sample Type	Tolerance Level	Target Blood-Lead Concentration		
		10 μg/dL	15 μg/dL	20 μg/dL
Floor Pb Loading ($\mu g/ft^2$) BRM Sampler	0.85	2	108	956
	0.90	Out of Range	31	319
	0.95	Out of Range	3	54
	0.99	Out of Range	Out of Range	2
Window Sill Pb Loading ($\mu g/ft^2$) BRM Sampler	0.85	41	3,138	38,277
	0.90	5	764	10,884
	0.95	Out of Range	65	1,456
	0.99	Out of Range	Out of Range	12
Window Well Pb Loading ($\mu g/ft^2$) BRM Sampler	0.85	1,797	339,046	> 1 Million
	0.90	173	59,738	> 1 Million
	0.95	4	3,079	131,989
	0.99	Out of Range	4	442
Floor Pb Loading ($\mu g/ft^2$) Wipe Samples	0.85	4	41	189
	0.90	1	22	95
	0.95	Out of Range	5	31
	0.99	Out of Range	Out of Range	1
Window Sill Pb Loading ($\mu g/ft^2$) Wipe Samples	0.85	49	687	3,079
	0.90	14	291	1,441
	0.95	2	64	426
	0.99	Out of Range	2	23
Window Well Pb Loading ($\mu g/ft^2$) Wipe Samples	0.85	230	42,597	714,210
	0.90	16	8,025	167,331
	0.95	Out of Range	359	15,874
	0.99	Out of Range	Out of Range	37

Table G2. Estimated Dust Pb Concentrations for Floors, Window Sills, and Window Wells at Which the 85th, 90th, 95th and 99th Percentiles of Childhood Blood Pb Concentrations Reach 10, 15, and 20 μg/dL (Based on the Least Squares Regression Models of the Rochester Lead-in-Dust Study Data)

Sample Type	Tolerance Level	Target Blood-Lead Concentration		
		10 μg/dL	15 μg/dL	20 μg/dL
Floor Pb Concentration (μg/g) BRM Sampler	0.85	Out of Range	5,33	107,321
	0.90	Out of Range	584	21,623
	0.95	Out of Range	Out of Range	1,333
	0.99	Out of Range	Out of Range	Out of Range
Window Sill Pb Concentration (μg/g) BRM Sampler	0.85	118	28,655	442,459
	0.90	6	5,438	108,134
	0.95	Out of Range	196	10,705
	0.99	Out of Range	Out of Range	16
Window Well Pb Concentration (μg/g) BRM Sampler	0.85	45	127,010	> 1 Million
	0.90	Out of Range	13,934	647,078
	0.95	Out of Range	83	31,183
	0.99	Out of Range	Out of Range	1

Table G3. Estimated Proportion of Children with Blood Pb Concentrations Greater than 10, 15, and 20 µg/dL as Predicted by Least Squares Regression Models of Blood Pb versus BRM Lead Loadings from Floors, Window Sills and Wells

Surface Tested	Pb Loading µg/ft²	Proportion Greater Than 10 µg/dl		Proportion Greater Than 15 µg/dl		Proportion Greater Than 20 µg/dl	
		Pr(Pb>10)	95% CI	Pr(Pb>15)	95% CI	Pr(Pb>20)	95% CI
Floors	5	0.13	(0.08 , 0.18)	0.03	(0.01 , 0.06)	0.01	(0.00 , 0.02)
	10	0.16	(0.11 , 0.21)	0.04	(0.02 , 0.07)	0.01	(0.00 , 0.02)
	15	0.18	(0.13 , 0.23)	0.05	(0.03 , 0.08)	0.01	(0.00 , 0.03)
	20	0.19	(0.14 , 0.25)	0.05	(0.03 , 0.09)	0.01	(0.01 , 0.03)
	25	0.20	(0.15 , 0.26)	0.06	(0.04 , 0.09)	0.02	(0.01 , 0.04)
	30	0.21	(0.16 , 0.27)	0.06	(0.04 , 0.10)	0.02	(0.01 , 0.04)
	35	0.22	(0.17 , 0.28)	0.07	(0.04 , 0.11)	0.02	(0.01 , 0.04)
	40	0.23	(0.18 , 0.29)	0.07	(0.04 , 0.11)	0.02	(0.01 , 0.04)
	100	0.29	(0.22 , 0.36)	0.1	(0.06 , 0.15)	0.04	(0.02 , 0.06)
	200	0.33	(0.25 , 0.42)	0.13	(0.08 , 0.19)	0.05	(0.02 , 0.09)
	250	0.35	(0.26 , 0.44)	0.14	(0.08 , 0.20)	0.05	(0.03 , 0.09)
Window Sills	50	0.11	(0.07 , 0.16)	0.02	(0.01 , 0.05)	0.00	(0.00 , 0.01)
	100	0.13	(0.09 , 0.18)	0.03	(0.01 , 0.06)	0.01	(0.00 , 0.02)
	200	0.16	(0.11 , 0.21)	0.04	(0.02 , 0.07)	0.01	(0.00 , 0.02)
	300	0.17	(0.13 , 0.23)	0.05	(0.03 , 0.08)	0.01	(0.00 , 0.03)
	400	0.19	(0.14 , 0.24)	0.05	(0.03 , 0.08)	0.01	(0.00 , 0.03)
	500	0.20	(0.15 , 0.25)	0.06	(0.03 , 0.09)	0.02	(0.01 , 0.03)
	600	0.20	(0.15 , 0.26)	0.06	(0.04 , 0.09)	0.02	(0.01 , 0.04)
	700	0.21	(0.16 , 0.27)	0.06	(0.04 , 0.10)	0.02	(0.01 , 0.04)
Window Wells	200	0.06	(0.03 , 0.11)	0.01	(0.00 , 0.03)	0.00	(0.00 , 0.01)
	500	0.07	(0.04 , 0.13)	0.01	(0.00 , 0.03)	0.00	(0.00 , 0.01)
	750	0.08	(0.05 , 0.13)	0.01	(0.00 , 0.04)	0.00	(0.00 , 0.01)
	800	0.08	(0.05 , 0.14)	0.01	(0.00 , 0.04)	0.00	(0.00 , 0.01)
	1500	0.10	(0.06 , 0.15)	0.02	(0.01 , 0.04)	0.00	(0.00 , 0.01)
	3000	0.11	(0.07 , 0.17)	0.03	(0.01 , 0.05)	0.00	(0.00 , 0.01)
	5000	0.13	(0.09 , 0.18)	0.03	(0.01 , 0.06)	0.01	(0.00 , 0.02)
	10000	0.15	(0.11 , 0.20)	0.04	(0.02 , 0.07)	0.01	(0.00 , 0.02)
	20000	0.17	(0.13 , 0.23)	0.05	(0.03 , 0.08)	0.01	(0.00 , 0.03)

Table G4. Estimated Proportion of Children with Blood Pb Concentrations Greater than 10, 15, and 20 μg/dL as Predicted by Least Squares Regression Models of Blood Pb versus Wipe Lead Loadings from Floors, Window Sills and Wells

Surface Tested	Pb Loading μg/ft²	Proportion Greater Than 10 μg/dl		Proportion Greater Than 15 μg/dl		Proportion Greater Than 20 μg/dl	
		Pr(Pb>10)	95% CI	Pr(Pb>15)	95% CI	Pr(Pb>20)	95% CI
Floors	5	0.11	(0.06 , 0.17)	0.02	(0.01 , 0.05)	0.00	(0.00 , 0 01)
	10	0.15	(0.11 , 0.21)	0.04	(0.02 , 0.07)	0.01	(0 00 , 0.02)
	15	0.18	(0.13 , 0.24)	0.05	(0.03 , 0.08)	0.01	(0.00 , 0.03)
	20	0.20	(0.16 , 0.26)	0.06	(0.04 , 0.10)	0.02	(0.01 , 0.04)
	25	0.22	(0.17 , 0.28)	0.07	(0.04 , 0.11)	0.02	(0.01 , 0.04)
	30	0.24	(0.19 , 0 30)	0.08	(0.05 , 0.12)	0.03	(0.01 , 0.05)
	35	0.26	(0.20 , 0.32)	0.09	(0.05 , 0.13)	0.03	(0.01 , 0.05)
	40	0.27	(0.21 , 0.34)	0.09	(0.06 , 0.14)	0.03	(0.01 , 0.06)
	100	0.36	(0.27 , 0.47)	0.15	(0.09 , 0.22)	0.06	(0 03 , 0.11)
	200	0 44	(0.32 , 0.58)	0.20	(0.12 , 0.31)	0.09	(0.04 , 0 16)
	250	0.47	(0.33 , 0.61)	0.22	(0.13 , 0.34)	0.10	(0.05 , 0.19)
Window Sills	50	0.10	(0.06 , 0.16)	0.02	(0.01 , 0.04)	0.00	(0.00 , 0.01)
	100	0.14	(0 10 , 0 19)	0.03	(0.02 , 0.06)	0.01	(0.00 , 0.02)
	200	0.19	(0.14 , 0.24)	0.05	(0.03 , 0.08)	0.01	(0.00 , 0.03)
	300	0.22	(0.17 , 0.28)	0 07	(0.04 , 0.10)	0.02	(0.01 , 0.04)
	400	0 24	(0.18 , 0 31)	0.08	(0.05 , 0.12)	0.03	(0.01 , 0.05)
	500	0 26	(0.20 , 0.33)	0.09	(0.05 , 0.13)	0.03	(0.01 , 0.05)
	600	0.28	(0.21 , 0.35)	0.10	(0.06 , 0 14)	0.03	(0.02 , 0 06)
	700	0.29	(0.22 , 0.37)	0.10	(0.06 , 0.16)	0.04	(0.02 , 0.07)
Window Wells	200	0.09	(0 05 , 0.15)	0 02	(0.01 , 0.04)	0.00	(0 00 , 0.01)
	500	0 12	(0.07 , 0 17)	0.03	(0.01 , 0.05)	0.00	(0.00 , 0.02)
	750	0.13	(0.08 , 0.18)	0.03	(0.01 , 0.06)	0.01	(0.00 , 0.02)
	800	0.13	(0.09 , 0.19)	0.03	(0.01 , 0.06)	0.01	(0.00 , 0.02)
	1500	0 15	(0.10 , 0.21)	0.04	(0.02 , 0.07)	0.01	(0 00 , 0.02)
	3000	0 17	(0.13 , 0 23)	0 05	(0.03 , 0 08)	0.01	(0.00 , 0.03)
	5000	0.19	(0 14 , 0 25)	0.06	(0.03 , 0.09)	0.02	(0.01 , 0.03)
	10000	0.22	(0.16 , 0.28)	0 07	(0.04 , 0.11)	0.02	(0.01 , 0.04)
	20000	0.25	(0.19 , 0.32)	0 08	(0.05 , 0.13)	0.03	(0.01 , 0.05)

APPENDIX H

PLOTS COMPARING THE ERRORS IN VARIABLES MODEL RESULTS FOR BRM AND WIPE SAMPLING

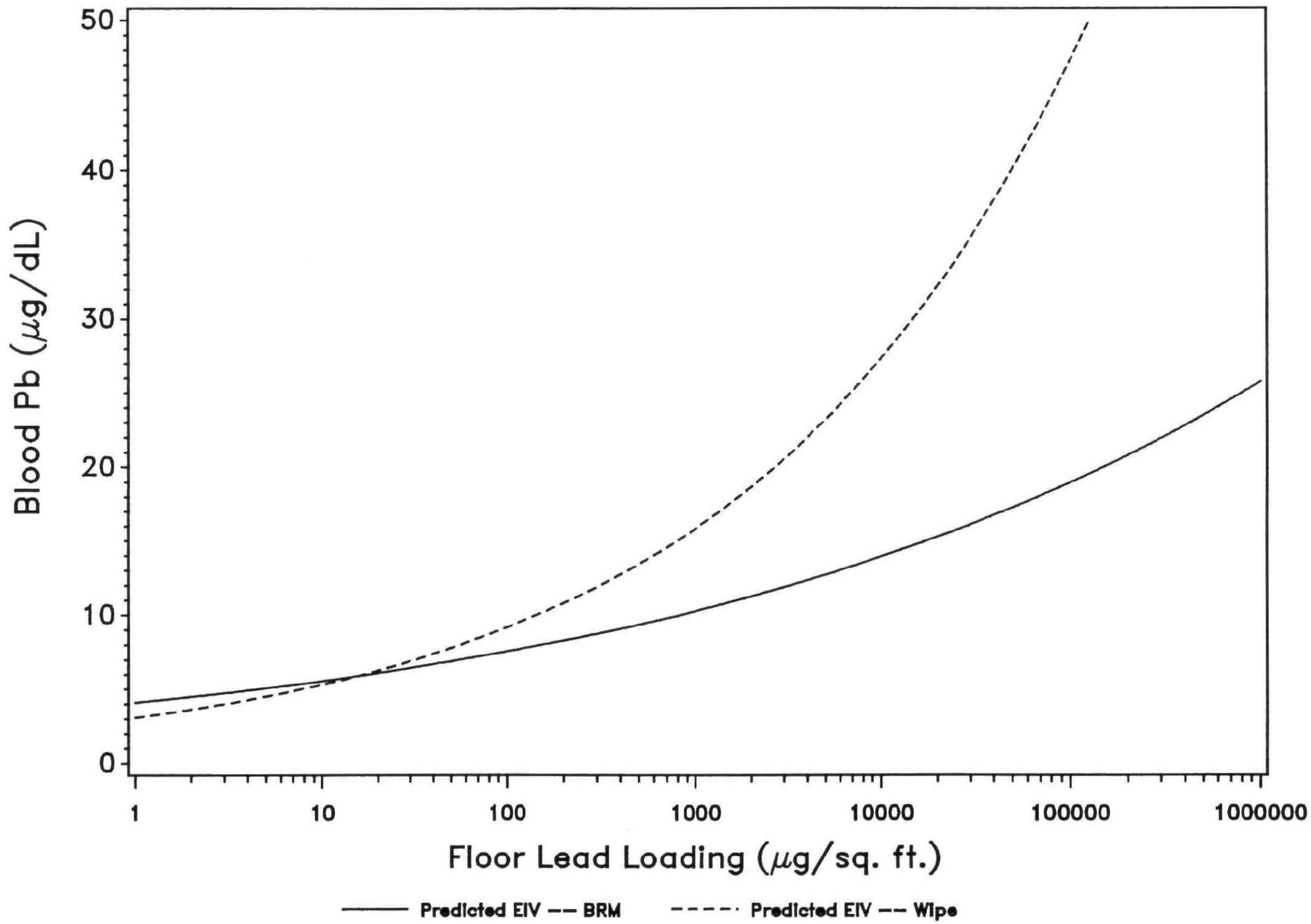

Figure H1. Rochester Lead-in-Dust Study Floor Lead Loadings -- Estimated Regression Curve for Errors in Variables Model From BRM and Wipe Sampling

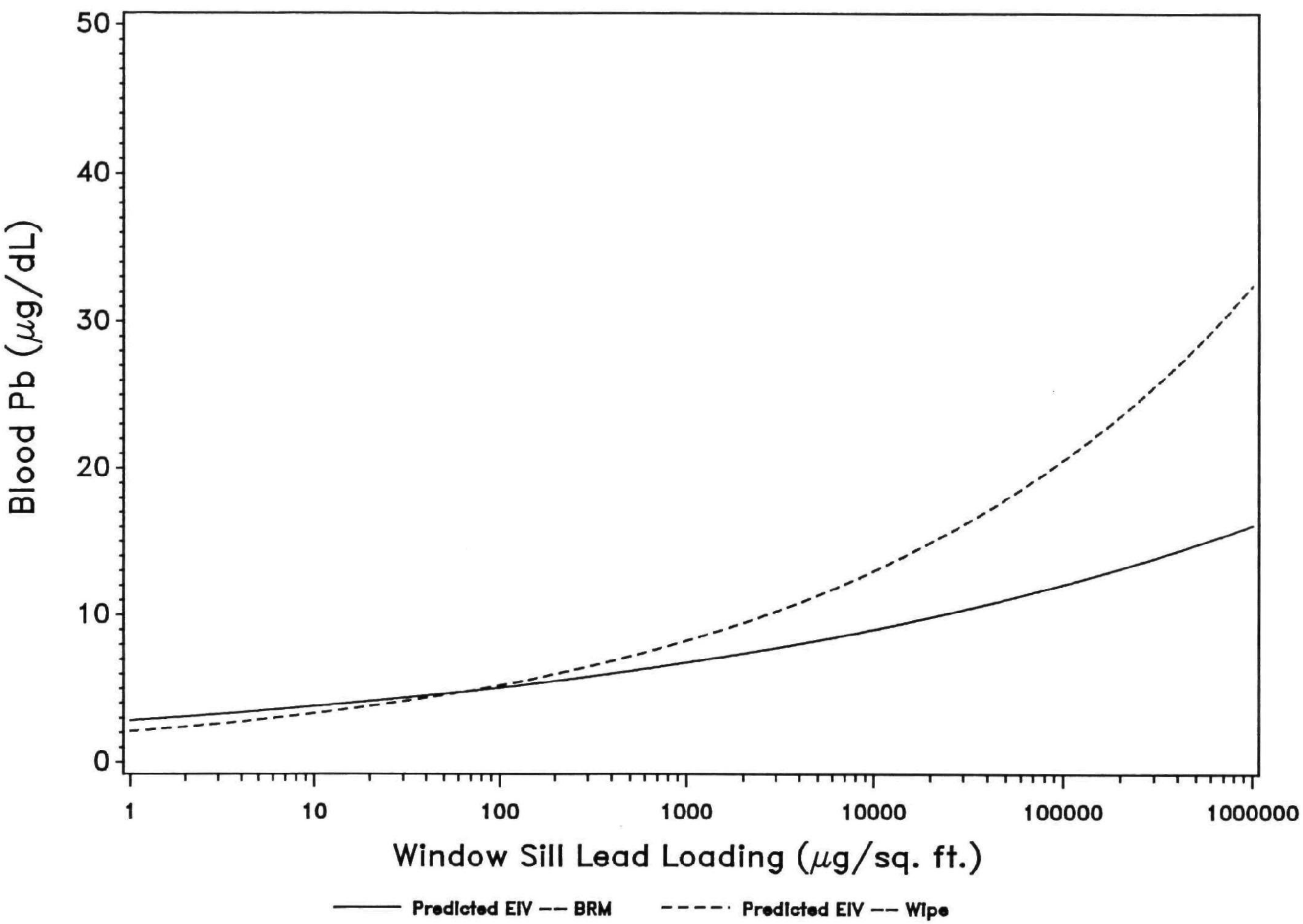

Figure H2. Rochester Lead-in-Dust Study Window Sill-Lead Loadings -- Estimated Regression Curve for Errors in Variables Model From BRM and Wipe Sampling

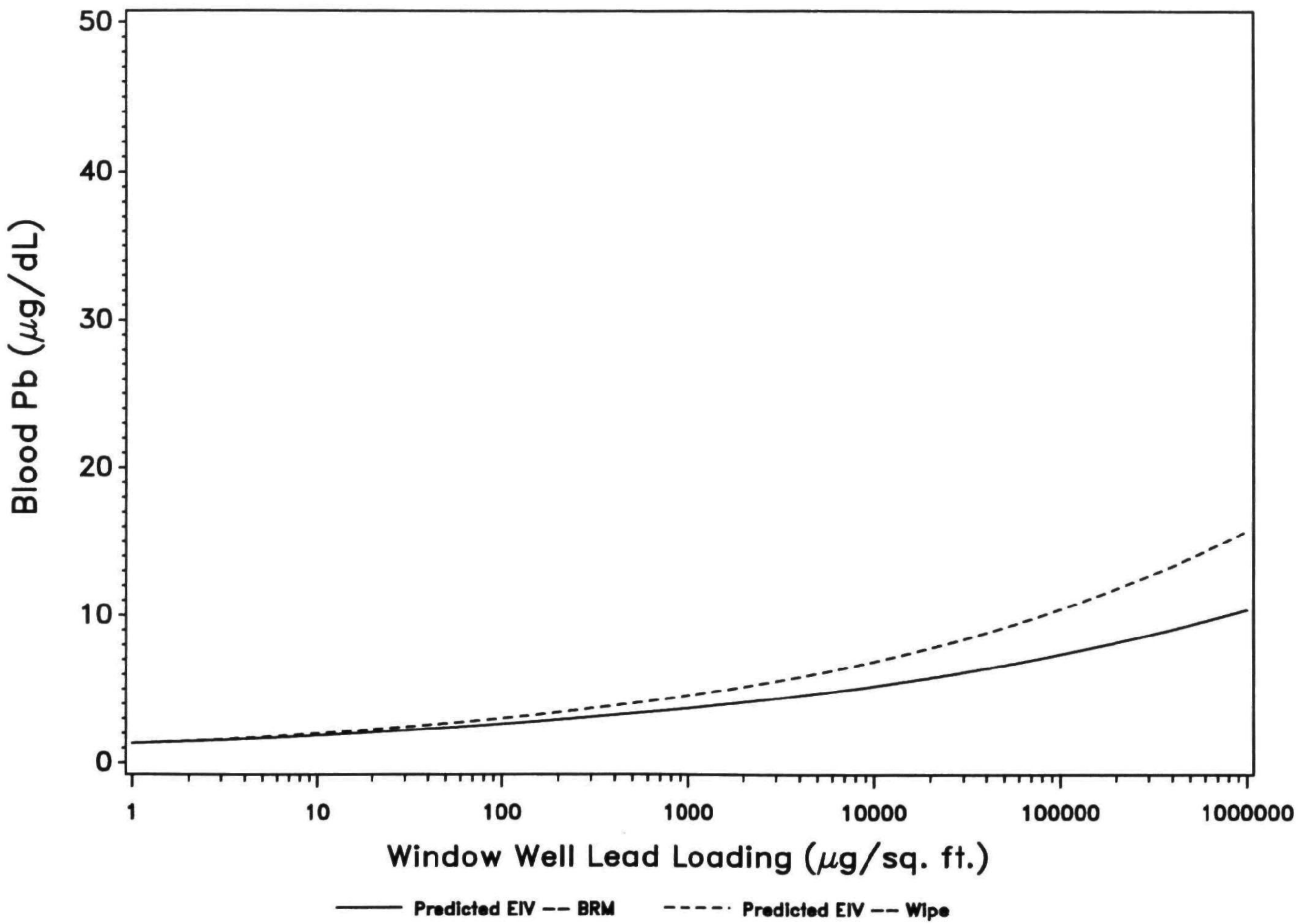

Figure H3. Rochester Lead-In-Dust Study Window Well-Lead Loadings -- Estimated Regression Curve for Errors in Variables Model From BRM and Wipe Sampling.