BUILDING A FRAMEWORK FOR HEALTHY HOUSING

Sustainability of Reduced Dust Lead Standards: Evidence from the HOME Study

Jonathan Wilson, MPP
National Center for Healthy Housing

2008 National Healthy Homes Conference ❖ September 15-17, 2008 in Baltimore, MD

HOME Study

- Health Outcomes and Measures of the Environment Study
- Conducted by the Cincinnati Children's Hospital Medical Center (Dr. Bruce Lanphear, PI) with support by NCHH
- Funded by NIEHS, EPA and HUD
- Field work between 2002-2008

HOME Study Purposes

- To quantify the impact of low-level fetal and early childhood exposures to environmental toxicants and child development.

- To test the effectiveness of home repairs to control lead hazards and injuries in early childhood.

HOME Study Design

- Longitudinal cohort study with a nested, randomized controlled trial.
- Families received either 1) targeted home repairs to control lead hazards or 2) placement of injury-control measures.
- Pregnant women recruited during a prenatal visit at around 16 weeks gestation in the Cincinnati area; homes repaired prior to birth of child; and home/children tracked for 3 years.

Core Elements of HOME Study Lead Hazard Controls

- Stabilize flaking, peeling or deteriorating lead-based paint
- Create smooth and easily cleaned floors and windows
- Install trough liners in windows to create a smooth and easily cleaned surface
- Replace windows if > 10% deterioration and lead-based paint present
- Extensive dust control and clearance testing
- Cover bare lead-contaminated soil in play areas with mulch or groundcover
- Install water filter if Pb concentration exceeds 2 ppb

Objectives Presented Today

Environmental Outcomes of Lead Hazard Control Group

- Are home repairs able to reduce PbD below 5, 50 and 400 µg/ft^2 on floors, window sills and troughs, respectively?
- Are dust lead reductions sustainable for at least one year?
- How would sustainability of alternative floor standards compare to current standards?

Demographics of Lead Cohort

- Housing:

  Age of Housing
  - 59% Pre-1940
  - 22% 1940-1960
  - 19% 1960-1978

  Tenure
  - 69% Owner-Occupied
  - 31% Rental

- Children/Families:

  Income
  - 22% <$30,000
  - 54% $30-80K
  - 24% >$80,000

  Race
  - 69% White
  - 24% Black
  - 7% Other

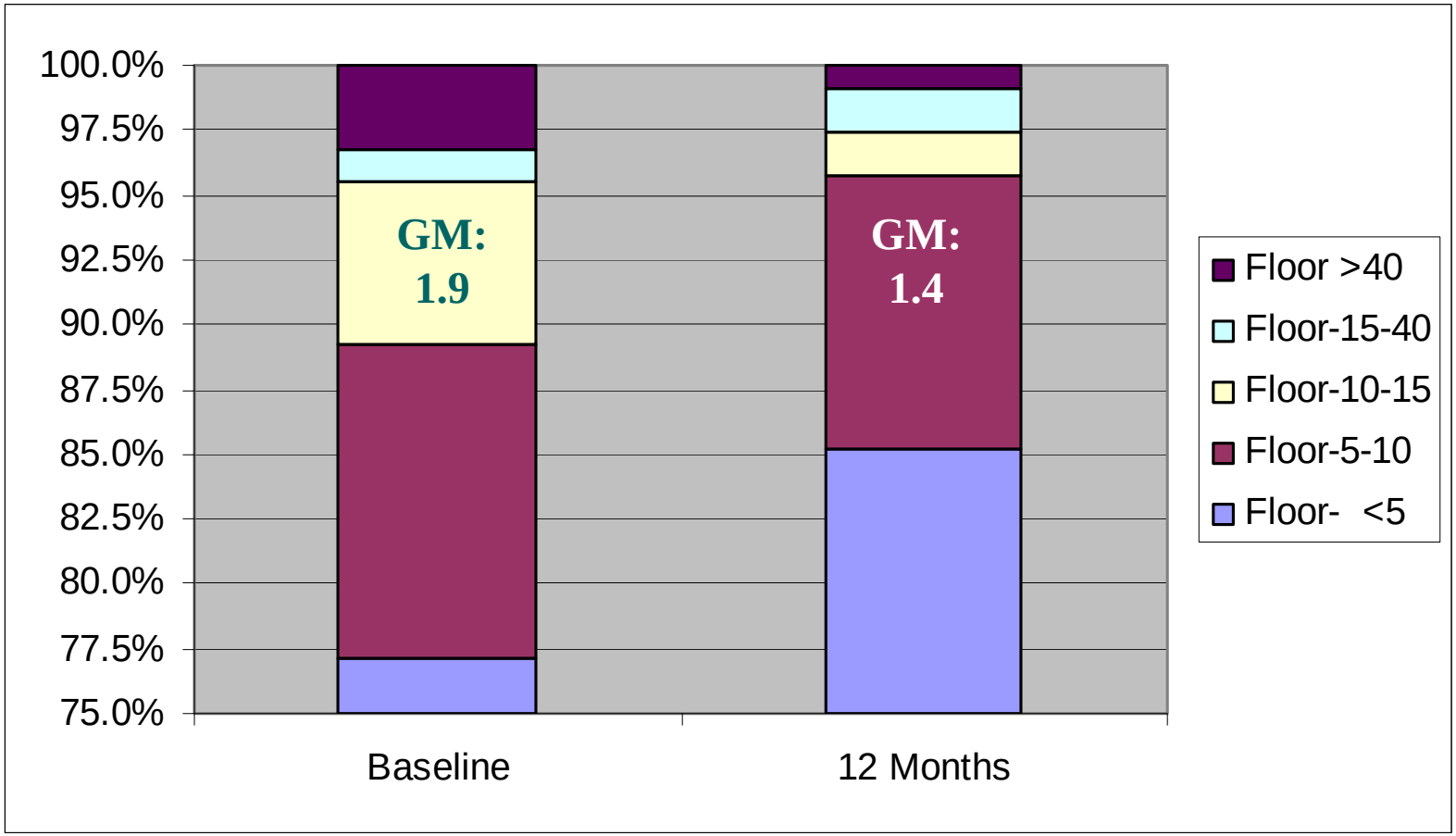
Baseline Dust Lead Loadings Household Arithmetic Mean

	GM ($\mu g/ft^2$)	95%tile ($\mu g/ft^2$)	Percent > Specified Levels		
Floor	**1.9**	**14.4**	> 40 $\mu g/ft^2$ **3.2%**	> 15 $\mu g/ft^2$ **4.5%**	> 5 $\mu g/ft^2$ **22.9%**
Sill	**40.9**	**895.7**	>250$\mu g/ft^2$ **17.9%**	>100$\mu g/ft^2$ **30.3%**	> 50 $\mu g/ft^2$ **42.8%**
Trough	**828.8**	**61,483**	>400$\mu g/ft^2$ **60.6%**		

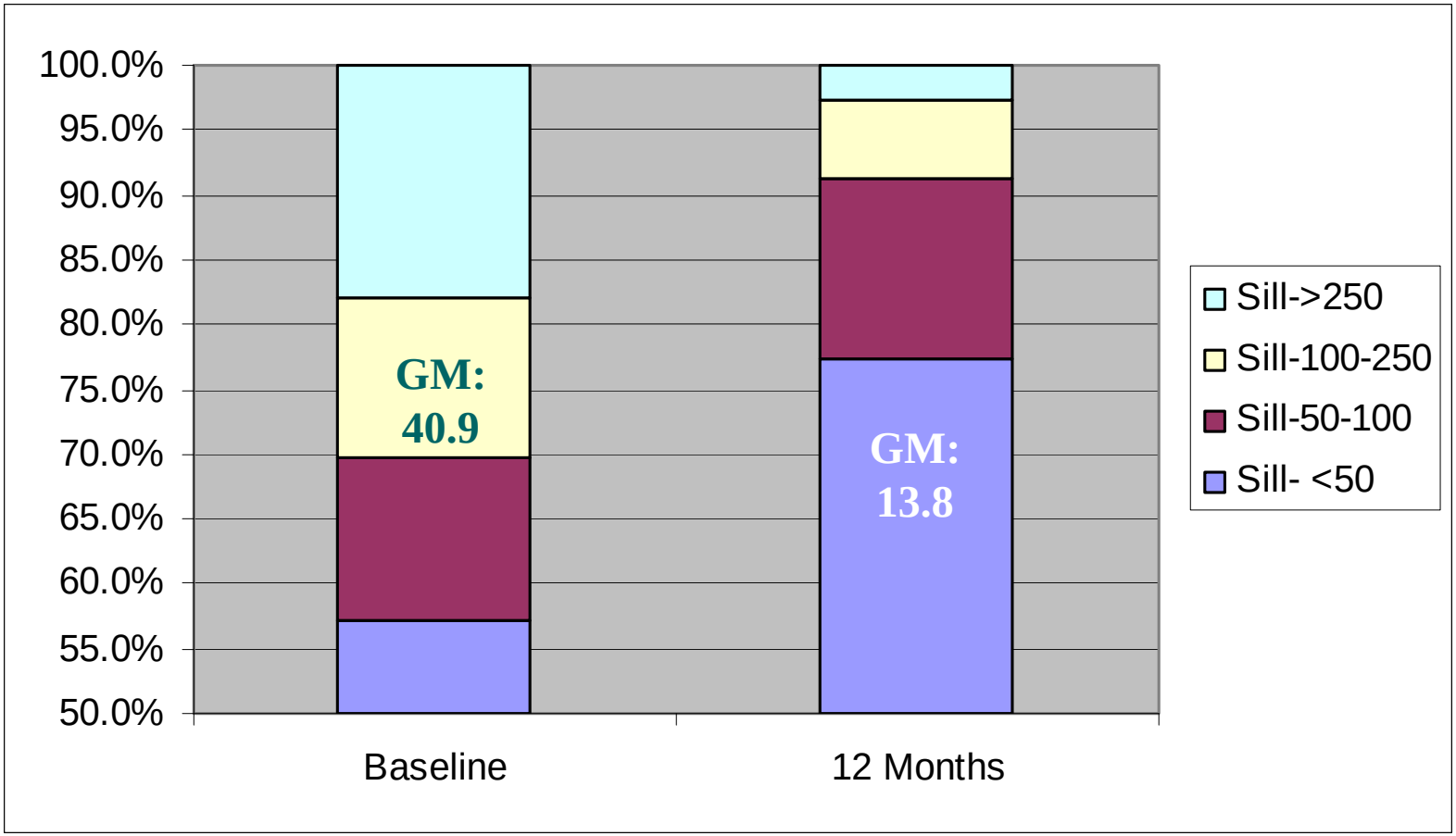
Target “Clearance” Levels Are Achievable

- Floors: 99% of homes (142/143) were below **5 µg/ft²** at “clearance”; one home had a value of 5.4 µg/ft²
- Sills: 100% of homes with sills (132) were below **50 µg/ft²** at “clearance”
- Troughs: 99% of homes with troughs (141/142) were below **400 µg/ft²** at “clearance”; one home had a value of 753 µg/ft²

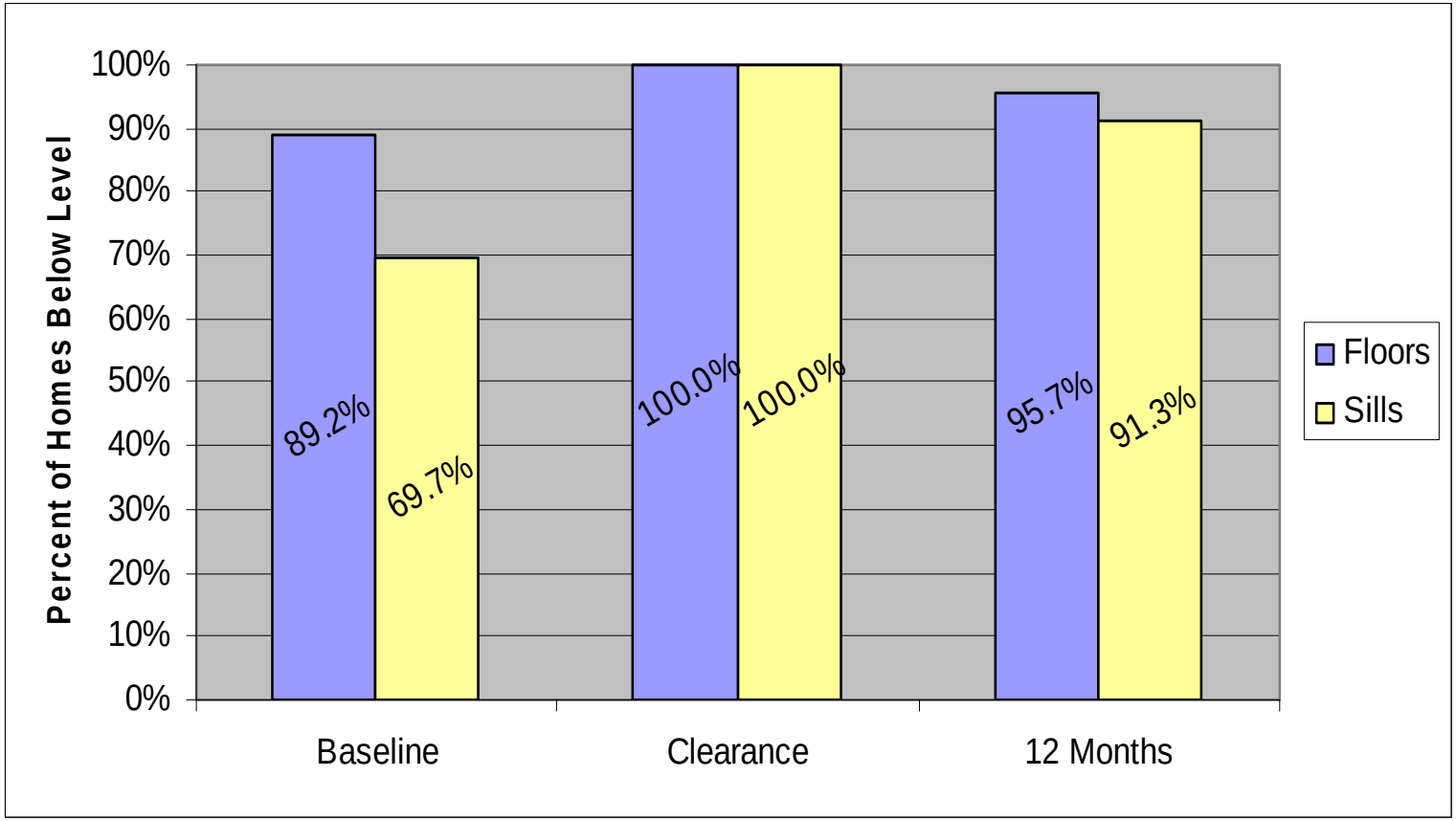
Percentage of Homes by Floor Dust Lead Range: Baseline and 12-Months



Percentage of Homes by Sill Dust Lead Range: Baseline and 12-Months



Sustainable Dust Lead Loadings Floors: 10 µg/ft²; Sills 100 µg/ft²



Disparities

- Chance of living in home with a current floor dust lead hazard at baseline compared to average household:
  - Black children: More than 3x as likely
  - Renters: More than 2x as likely
  - Incomes <$30K: More than 2x as likely
- All three groups were more than 2 times as likely to live in a home with a floor level of *10 µg/ft^2.*

Comparison with Alternate Floor Standard

Standard	Percent exceedance baseline	Percent exceedance 12 months	Reduction
40 µg/ft^2	3.2%	0.9%	72%
10 µg/ft^2	10.8%	4.3%	60%

Comparison with Alternate Window Sill Standard

Standard	Percent exceedance baseline	Percent exceedance 12 months	Reduction
250 µg/ft^2	17.9%	2.6%	85%
100 µg/ft^2	30.3%	8.7%	71%

Alternate Standard and Disparities

- Families earning less than $30,000, Blacks and renters had lower reductions in percentages of homes exceeding the alternate standards (10, 100) than the overall study population:

	Floors	Sills
Rental:	-49%	-49%
Black:	-54%	-46%
Lower Income:	-29%	-36%
Overall:	**-60%**	**-71%**

Conclusions

- Floor and sill clearance levels of 5 and 50 µg/ft^2 are achievable with ordinary lead hazard control practices but at least 15% of units exceeded these levels after one year
- A floor dust lead standard of 10 µg/ft^2 is achievable at clearance and can be sustained for at least one year (less than 5% exceedance)
- A sill dust lead standard of 100 µg/ft^2 is achievable at clearance and can be sustained for at least one year (less than 10% exceedance)

Conclusions (2)

- The number of units in this study that would have been classified as having hazards would increase from 19% to 32% based on levels of 10 and 100 µg/ft^2
- Additional attention will be needed to address the homes of at-risk populations. Dust lead levels were substantially reduced in these populations but disparities were not reduced

Acknowledgments, Disclaimers and Contact Information

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The Case For Revising The Lead Dust Standard

David E. Jacobs, PhD, CIH
National Center for Healthy Housing

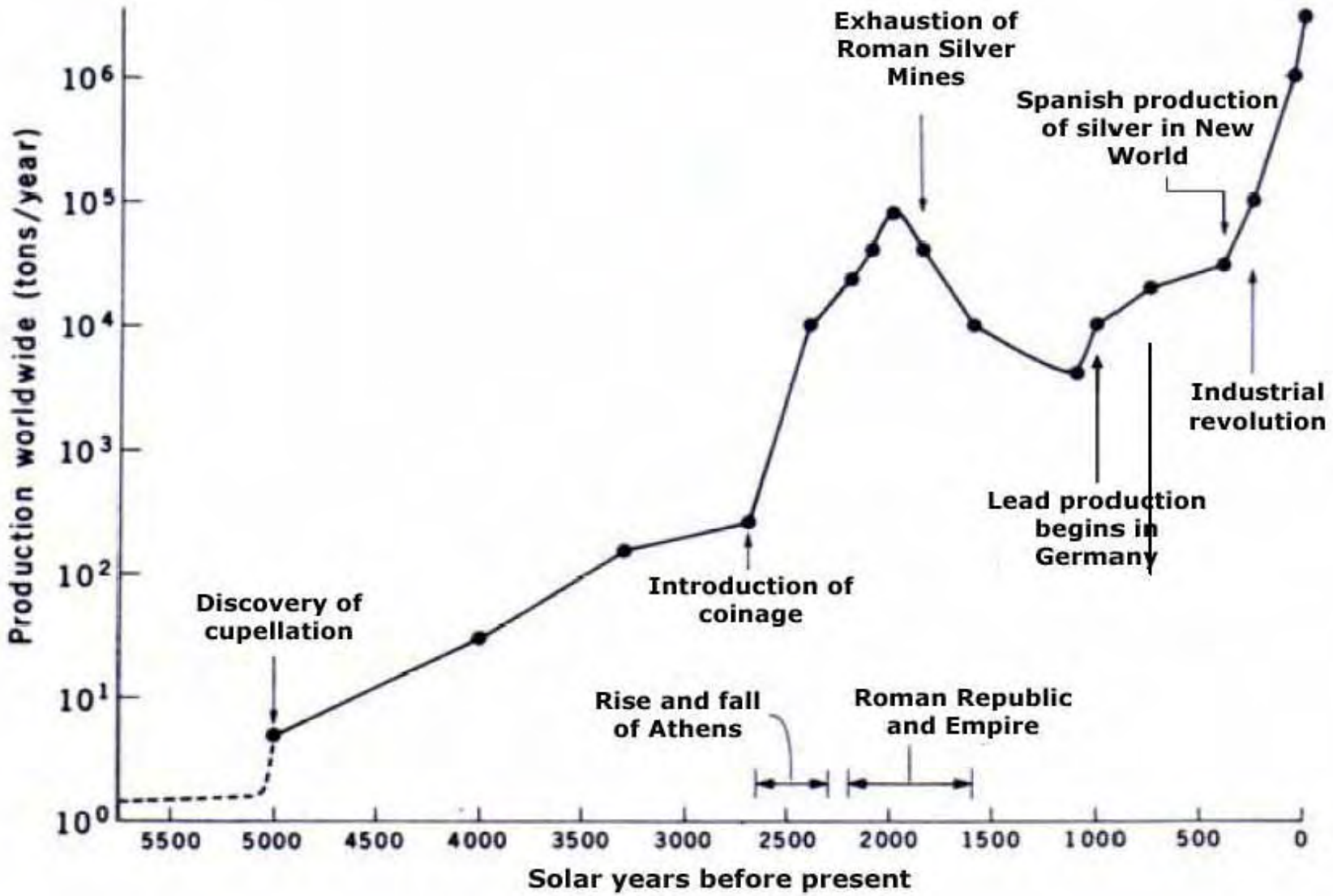
2008 National Healthy Homes Conference ❖ September 15-17, 2008 in Baltimore, MD

Outline

- Are Current Lead Exposures High or Low?
- Evidence of PbD, PbB and Health
- PbD and Importance in Cost-Benefit
- Considerations in Setting a PbD Standard
  - Health, Feasibility and Measurement Limits
- History of PbD standards
- New Recommended Standard

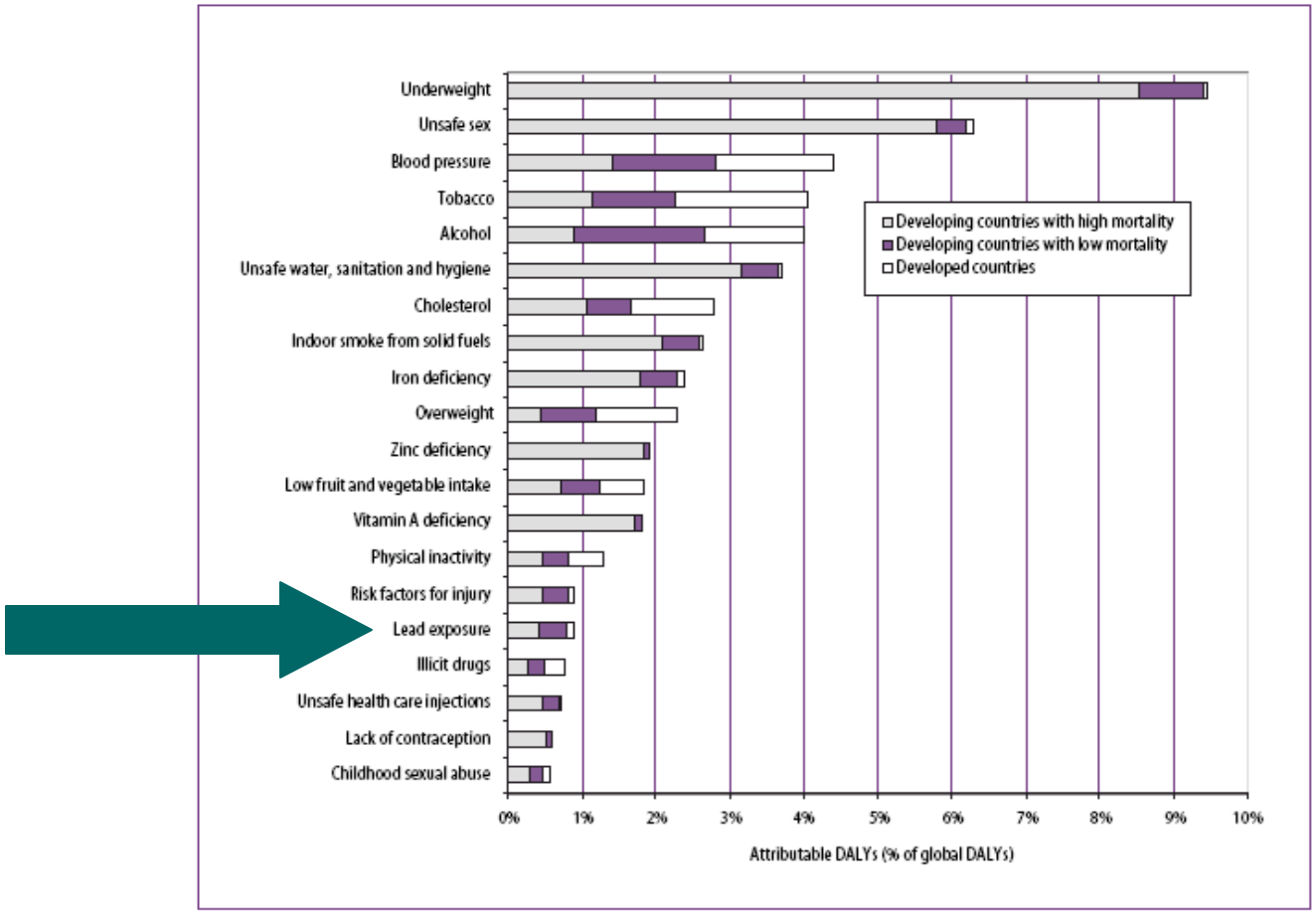
(Note: PbD = Lead in Dust, PbB = Lead in Blood)

Long-Term Lead Production Increase



Global Distribution of Burden of Disease
Lead = 16th in DALYs (WHO 2002)

Figure 4.9 Global distribution of burden of disease attributable to 20 leading selected risk factors



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Research | Children's Health

Low-Level Environmental Lead Exposure and Children's Intellectual Function: An International Pooled Analysis

Bruce P. Lanphear,[1,2] Richard Hornung,[1,2,3] Jane Khoury,[1,2] Kimberly Yolton,[1] Peter Baghurst,[4] David C. Bellinger,[5] Richard L. Canfield,[6] Kim N. Dietrich,[1,2] Robert Bornschein,[2] Tom Greene,[7] Stephen J. Rothenberg,[8,9] Herbert L. Needleman,[10] Lourdes Schnaas,[11] Gail Wasserman,[12] Joseph Graziano,[13] and Russell Roberts[14]

Environ Health Perspect 113: 894-899 (2005)

Slope of PbB < 10 µg/dL

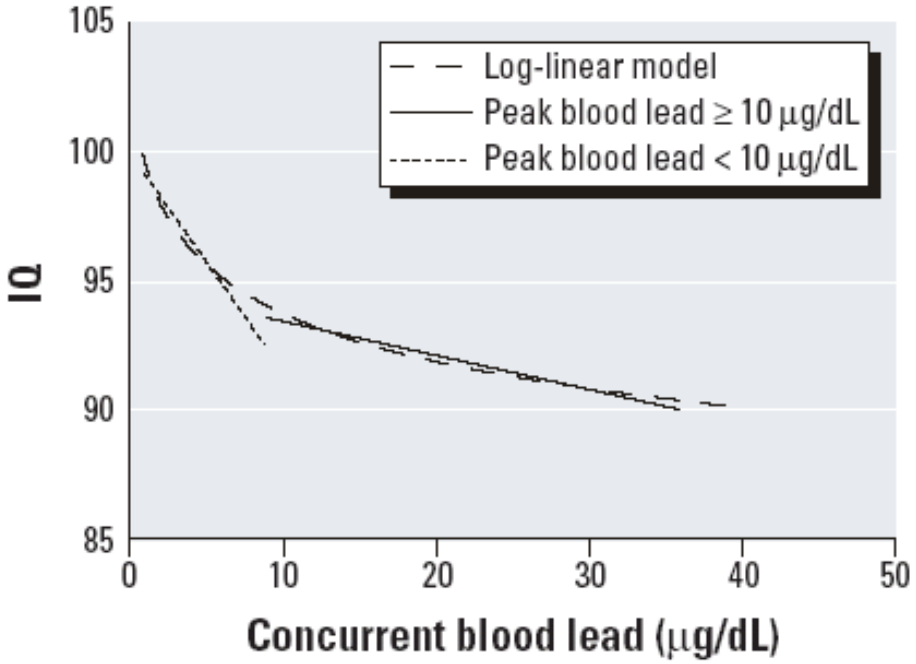
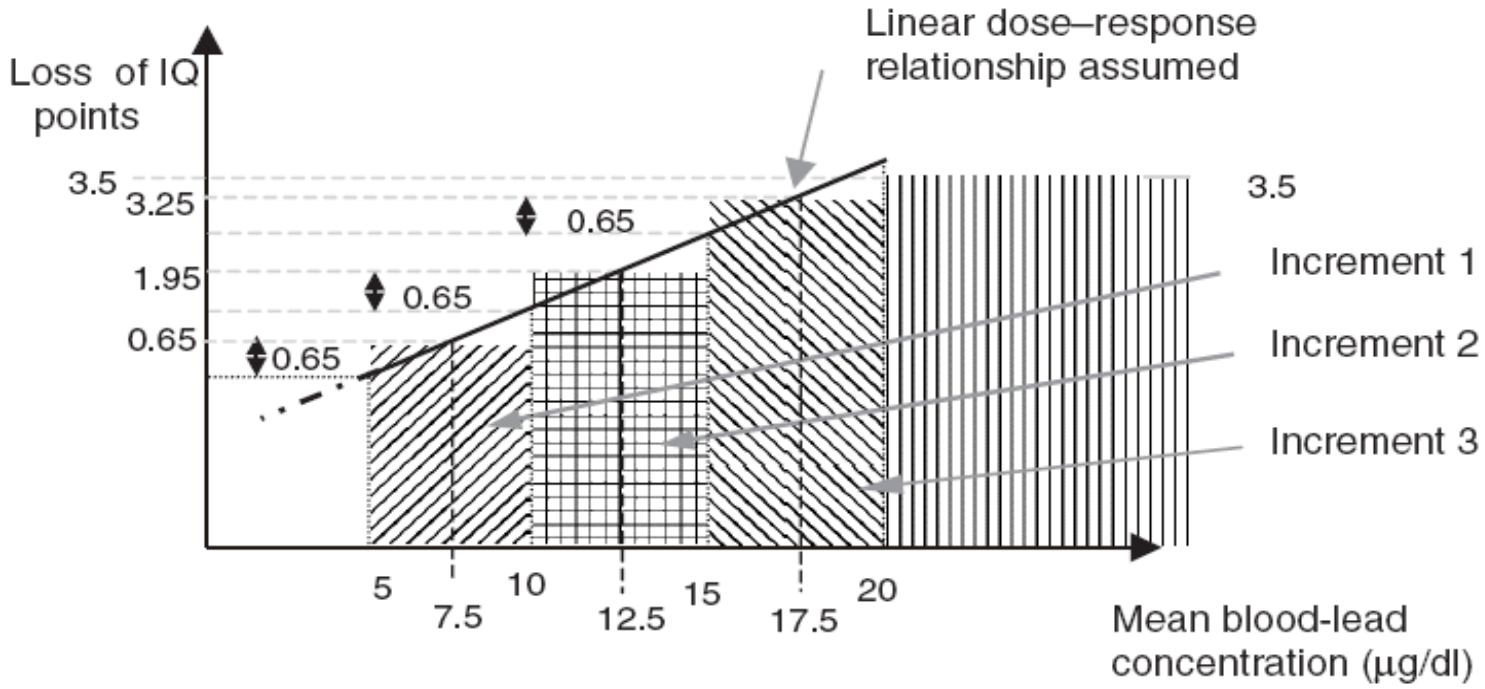


Figure 4. Log-linear model for concurrent blood lead concentration along with linear models for concurrent blood lead levels among children with peak blood lead levels above and below 10 µg/dL.

2003 WHO Analysis

Figure 19.3 Decrease in IQ points per increment increase in blood-lead concentration ("best estimate")



WHO Update

- 2003 analysis may have underestimated the impact of lead on IQ in the lower exposure range by as much as 66%.
- Most of the population is in the lower exposure range.
- The 2003 WHO analysis is now being updated, likely to show increase in DALYs

Threshold

- 1991 CDC Statement
  - No Dose Below Which Harmful Effects Are Not Observed
- Harmful Effects at < 5 µg/dL
  - Lanphear and many others
- 2007 – CDC Guidance issued for cases below 10 µg/dL

New CDC Guidance < 10 µg/dL

PEDIATRICS®

OFFICIAL JOURNAL OF THE AMERICAN ACADEMY OF PEDIATRICS

Interpreting and Managing Blood Lead Levels of Less Than 10 µg/dL in Children and Reducing Childhood Exposure to Lead: Recommendations of the Centers for Disease Control and Prevention Advisory Committee on Childhood Lead Poisoning Prevention

Helen J. Binns, Carla Campbell, Mary Jean Brown and for the Advisory Committee on Childhood Lead Poisoning Prevention

Pediatrics 2007;120;e1285-e1298

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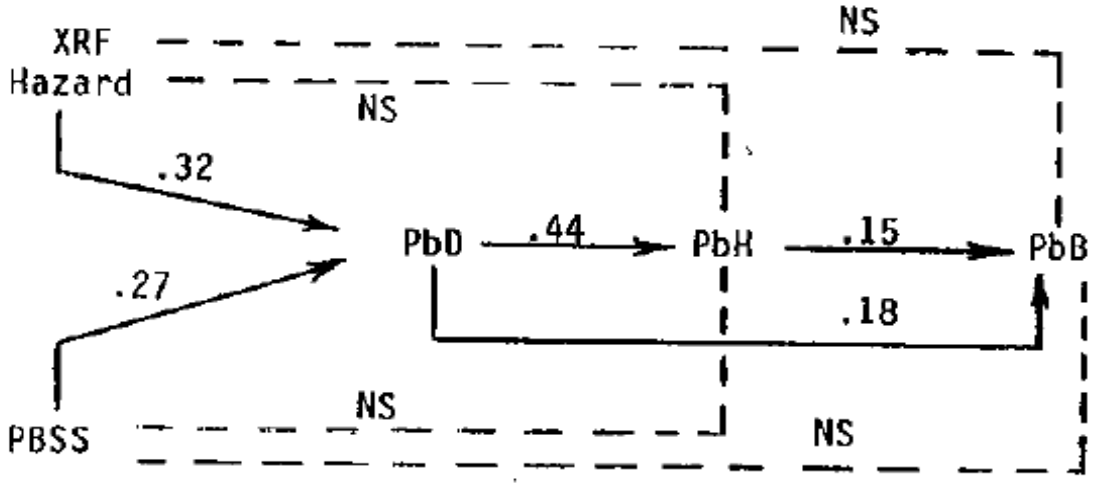
Evolution of Lead Exposure Pathway Analysis

(Bornschein et al. 1986)

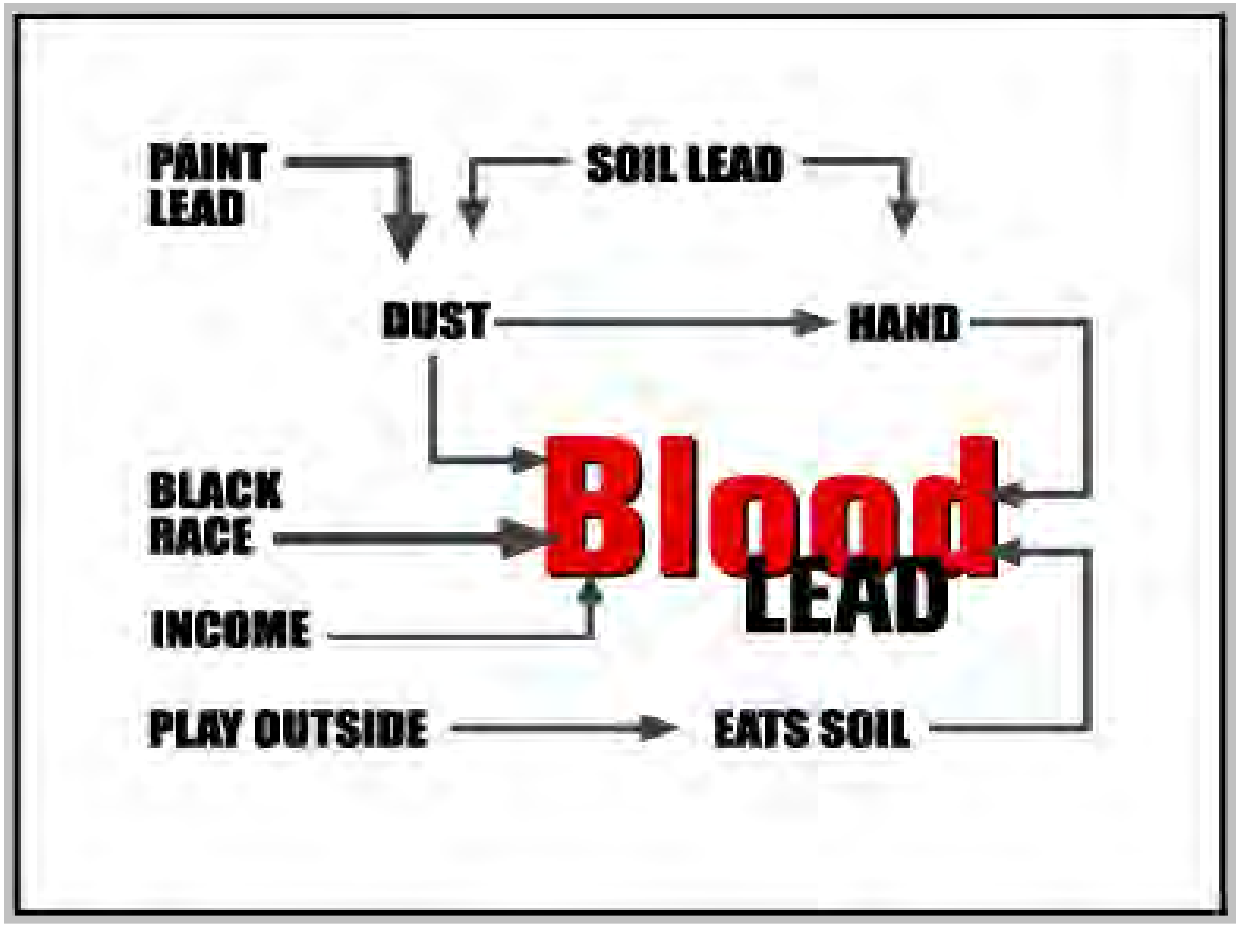


Structural Equations:

	R^2
Ln(PbB) = 1.276 + .152 Ln (PbH) + .182 Ln (PbD)	.38
Ln(PbH) = -0.966 + .444 Ln (PbD)	.22
Ln(PbD) = 4.691 + .325 Ln (XRFHAZ) + .268 Ln (PbSS)	.52

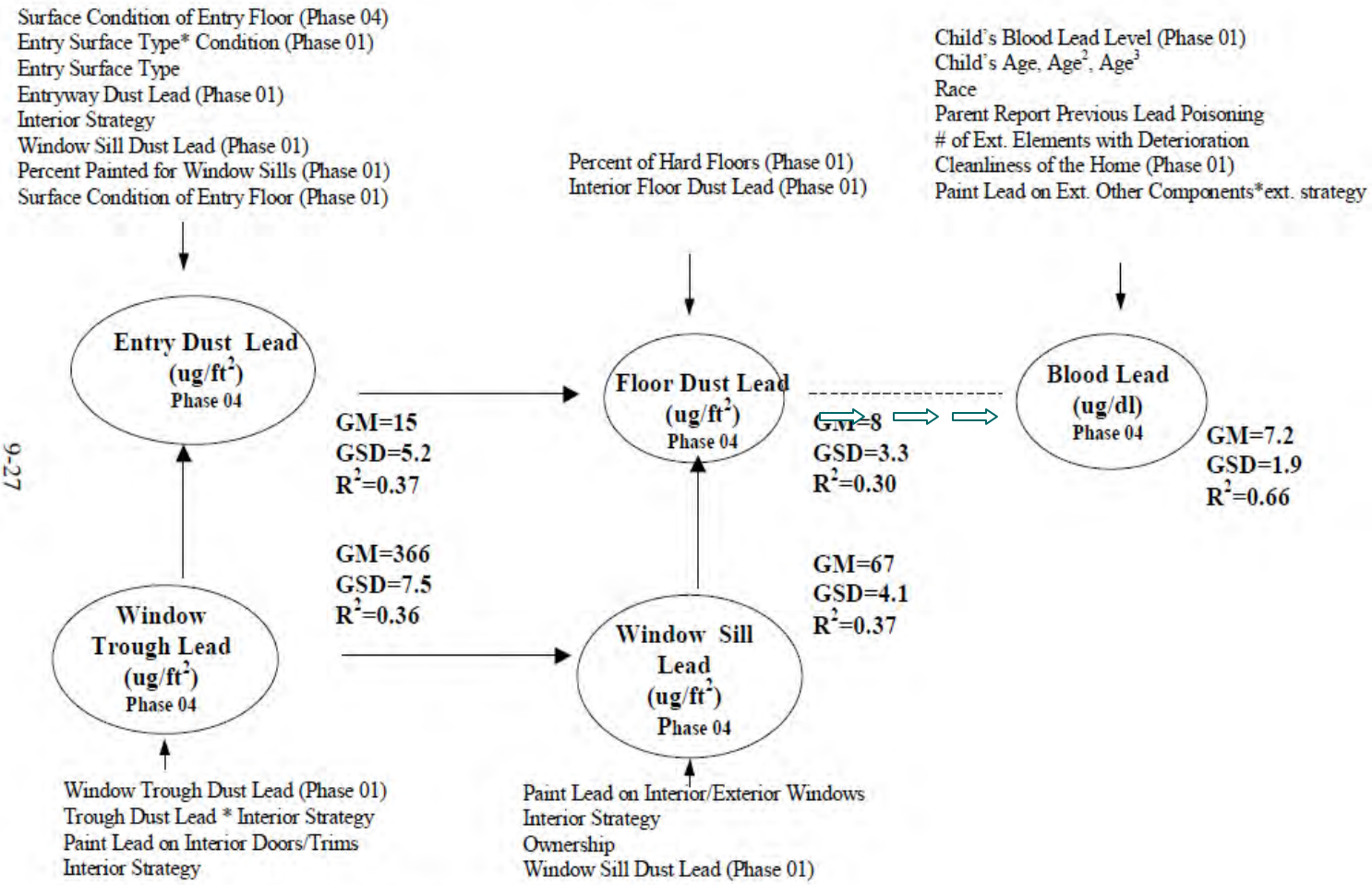
All coefficients are significant at p<.05;NS=Not Significant

Pathways of Childhood Lead Exposure (1990s)



Twelve-Month Post-Intervention Lead Exposure Pathways Including Blood Lead

(Data as of: June 1, 2000)
(N = 155)



Note: Solid line indicates that a statistically significant coefficient was found.
Dash line indicates that no statistically significant coefficient was found.
All coefficients are significant at $P<0.05$

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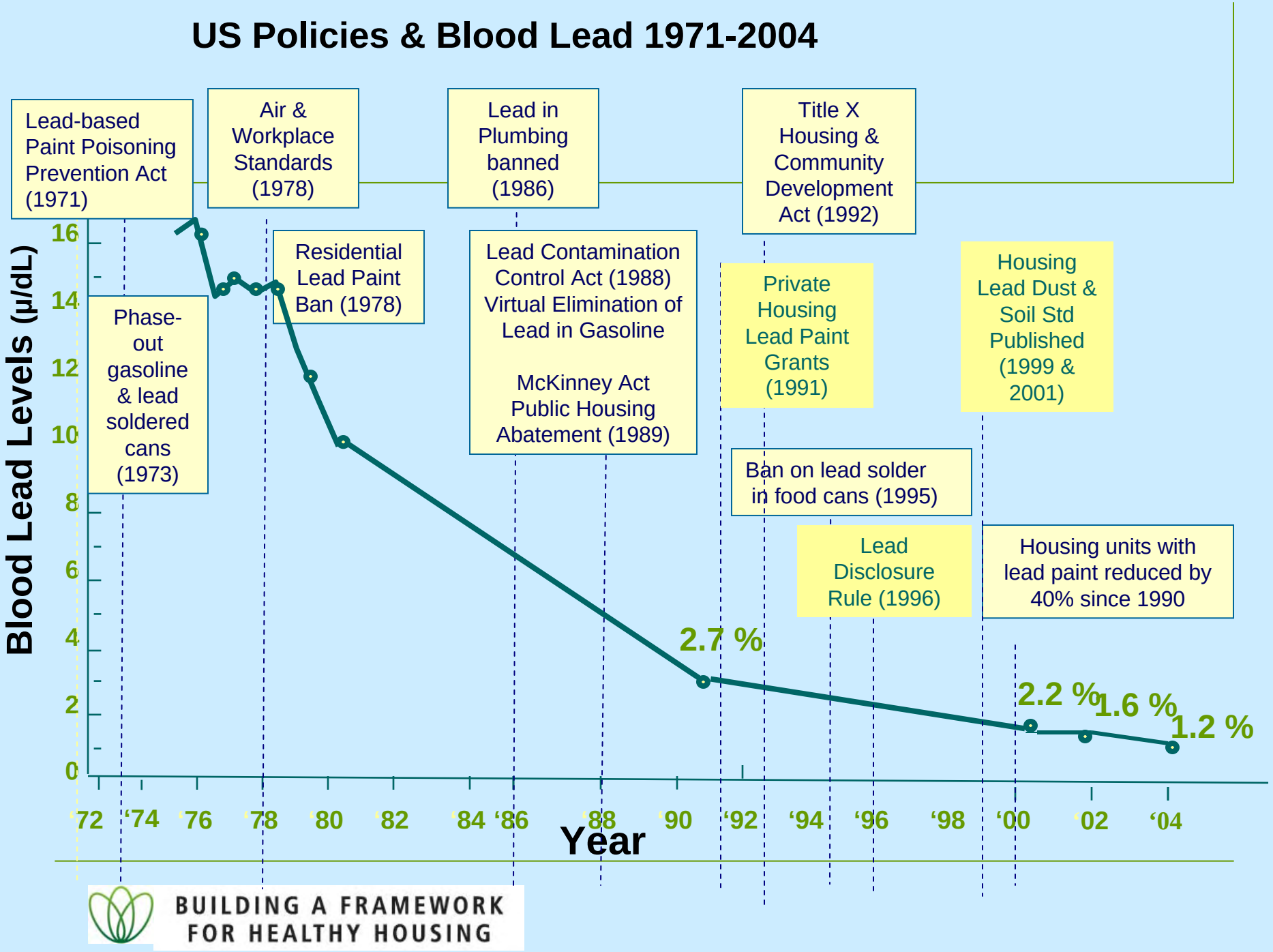
DUST


Newsweek
July 15, 1991
LEAD
And Your Kids
Disturbing New Evidence About the Threat to Their Health
How to Protect Them

US Policies & Blood Lead 1971-2004



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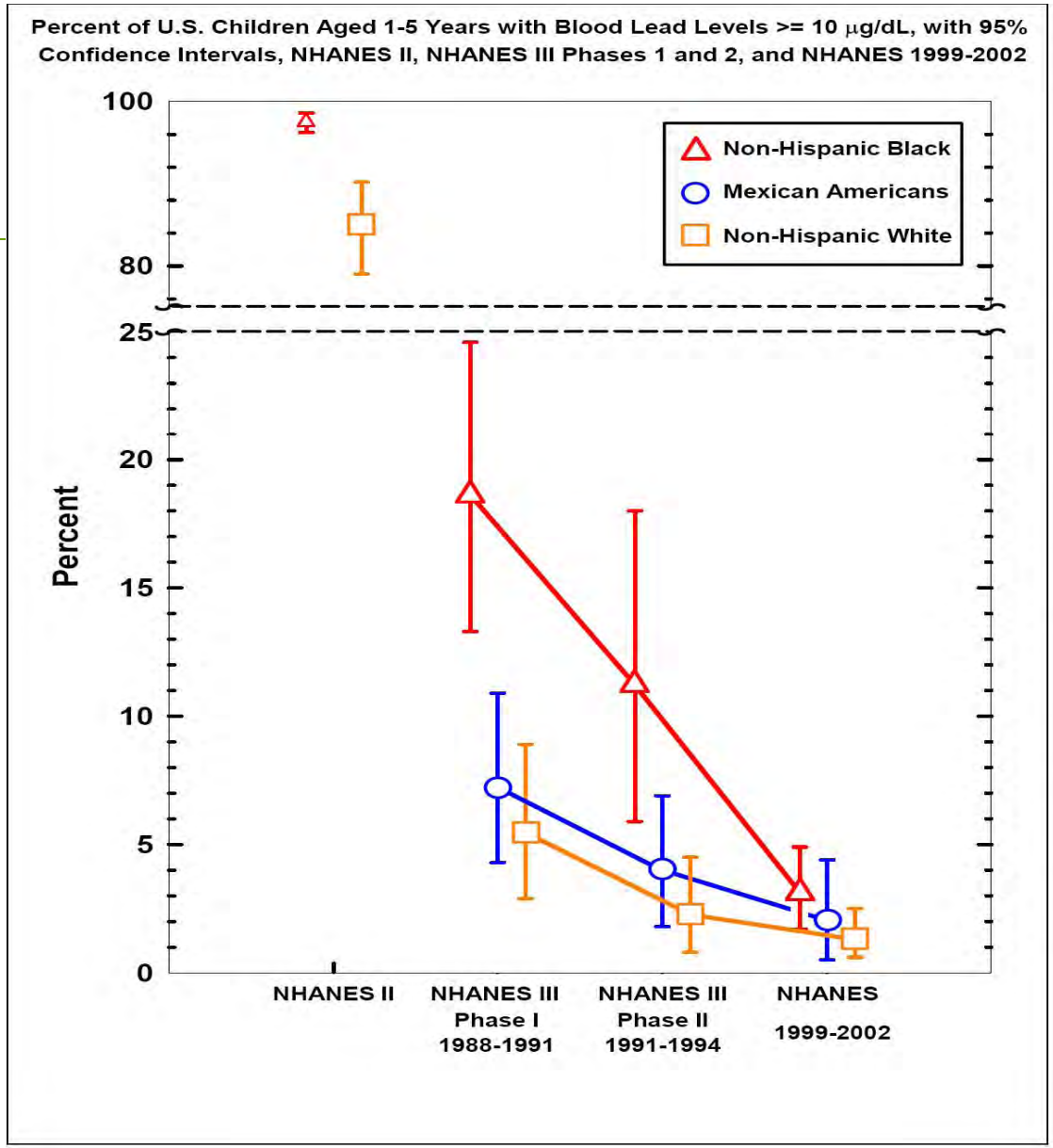
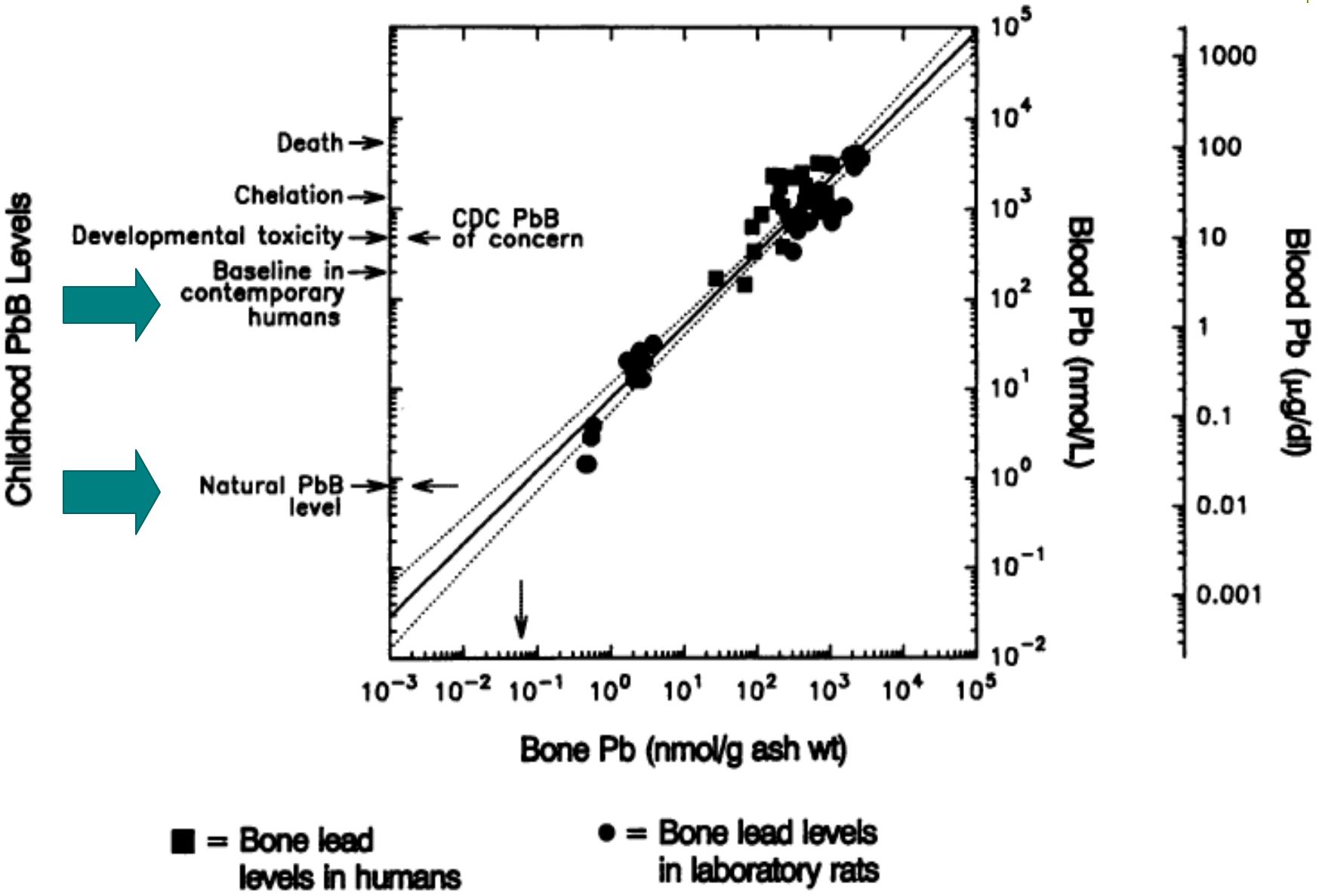
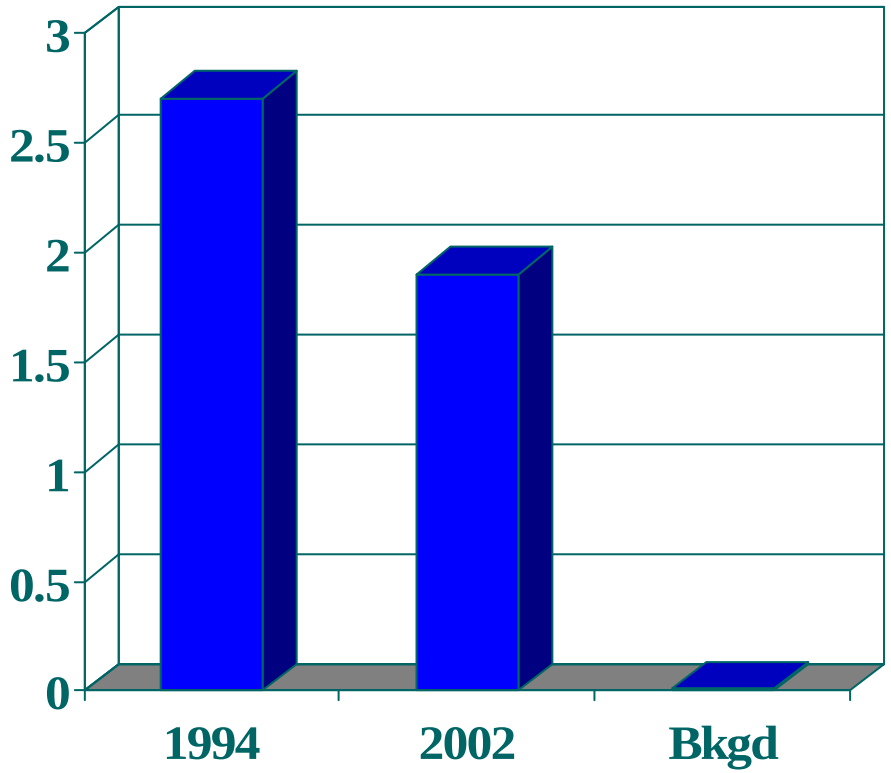

Percent of U.S. Children Aged 1-5 Years with Blood Lead Levels >= 10 μg/dL, with 95% Confidence Intervals, NHANES II, NHANES III Phases 1 and 2, and NHANES 1999-2002
Non-Hispanic Black
Mexican Americans
Non-Hispanic White
Percent
100
80
25
20
15
10
5
0
NHANES II
NHANES III Phase I 1988-1991
NHANES III Phase II 1991-1994
NHANES 1999-2002

Has the Lead Problem Already Been Solved?


Childhood PbB Levels
Death
Chelation
Developmental toxicity
Baseline in contemporary humans
Natural PbB level
CDC PbB of concern
Bone Pb (nmol/g ash wt)
Blood Pb (nmol/L)
Blood Pb (µg/dl)
■ = Bone lead levels in humans
● = Bone lead levels in laboratory rats

US Childhood PbB Compared to "Natural" Background PbB



Bkgd = 0.016 ug/dL (Flegal 1986)

The Lead Experience

- A Public Health Success Story
- A “Pyrrhic Victory”

- Future Challenges are Large
  - How Large Are They?

Settled Dust Lead & Paint Lead

- Current definition of lead paint = 1 mg/cm^2
- Sand a one square foot area into dust
- Spread the dust over a 10 ft x 10 ft room
- Resulting lead dust loading = 9,300 ug/ft^2
- Current US Government Limit = 40 ug/ft^2

How Much Lead Paint Is Left?

- 7.5 billion square feet interior
- 29.2 billion square feet exterior

- Total = **36.7 billion square feet**

Source: HUD National Survey of Lead and Allergens, 2000

Cost -Benefit & PbD

Value per IQ point (A)	$16,809		
IQ per 1 ug/dL (B)	0.52		
Value per avoided 1 ug/dL (A x B)	$8,741		
Benefit in Units with Lead Paint on Window Surfaces	**Pre-1940**	**1940-1959**	**1960-1977**
Lead dust hazard prevalence (C)	56%	43%	34%
Avoided ug/dL (D)	4.33	4.33	2.44
Average benefit per resident child (E = A x B x C x D)	$21,195	$16,275	$7,251
Benefit in Units without Lead Paint on Window Surfaces			
Lead dust hazard prevalence (F)	N.A.	17%	6%
Avoided ug/dL (G)	N.A.	2.44	1.98
Average benefit per resident child (H = A x B x F x G)	N.A.	$3,626	$1,038
Percent of single-pane window housing units with lead paint on interior window surfaces (I)	100%	40%	19%
Weighted Average Benefit per resident child (J = (E x I) + (H x (1 - I)))	**$21,195**	**$8,685**	**$2,219**
Number of Children ages 6-30 months per unit (K)	0.068	0.069	0.060
Number of Children ages children ages 6-18 months per unit (L)	0.034	0.0345	0.030
Year 1 Average Benefit per unit (J x K)	$1,441	$599	$133
Years 2-10 Average Benefits per unit (J x L)	$721	$300	$67
Present Value Benefit per unit over 10 years	**$6,847**	**$2,847**	**$632**

Available online at www.sciencedirect.com
ScienceDirect
Environmental Research 106 (2008) 410–419
Environmental Research
www.elsevier.com/locate/envres

Monetary benefits of preventing childhood lead poisoning with lead-safe window replacement

Rick Nevin[a,*], David E. Jacobs[a], Michael Berg[b], Jonathan Cohen[b]

[a]National Center for Healthy Housing, USA
[b]ICF International, USA

Total Net Benefits of Lead Safe Window Replacement

- Pre-1940 Housing
  - $5,092 x 11 million units with single pane lead contaminated windows = $56 billion
- Pre-1960 Housing
  - $1, 092 x 11 million units with single pane lead contaminated windows = $11 billion
  - **Total = $67 billion**

Other Non-Monetized Benefits

- Direct Medical Care
- Avoided Special Education
- Avoided Attention Deficit Hyperactivity Disorder
- Special Property Maintenance
- Stress on Parents & Children
- Premature Mortality & Memory Loss
- Treatment of dental caries associated with lead exposure
- Liver, kidney and other diseases associated with lead exposure
- Avoided Lead Litigation
- Lead-associated criminal behavior costs


CALVIN & HOBBES BILL WATTERSON
I'M SIGNIFICANT!

US Dust Lead Standard (1999 & 2001)

- Floors = 40 µg/ft^2
- Interior Window Sills = 250 µg/ft^2
- Set in 1999 – 2001, based on data from mid-1990s

Dust Lead Standards

- Are they health-based?
  - Blood Lead Level
  - Probability of Exceedance
- Are they attainable?
- Can typical and high risk dwellings meet them over time?
- Are they measurable?

History of Floor PbD Std

- Bioavailable PbD fraction
  - 200 µg/ft^2 (Farfel et al. - Baltimore Late 1980s), based on PbB of 25 µg/dL
- Total Pb PbD
  - 100 µg/ft^2 (EPA Guidance, 1995)
  - 40 µg/ft^2 (HUD Std.1999)
  - 40 µg/ft^2 (EPA Std. 2001)

ENVIRONMENTAL RESEARCH, SECTION A 79, 51–68 (1998)
ARTICLE NO. ER983859

The Contribution of Lead-Contaminated House Dust and Residential Soil to Children's Blood Lead Levels

A Pooled Analysis of 12 Epidemiologic Studies[1]

Bruce P. Lanphear,* Thomas D. Matte,† John Rogers,‡ Robert P. Clickner,‡ Brian Dietz,‡ Robert L. Bornschein,§ Paul Succop,§ Kathryn R. Mahaffey,¶ Sherry Dixon,‖ Warren Galke,‖ Michael Rabinowitz,** Mark Farfel,†† Charles Rohde,‡‡ Joel Schwartz,§§ Peter Ashley,¶¶ and David E. Jacobs¶¶

TABLE 5

Likelihood of a Child's Blood Lead ≥ 10 μg/dL for Floor Dust Lead Loadings and Exterior Exposure Levels (ppm)[a]

Dust lead loading (μg/ft²)	Probability of blood lead greater than 10 μg/dL							
	Exterior lead exposure (ppm)							
	10	72[b]	100	500	1000	1500	2000	4000
1	0.33% (0.05, 2.24)	1.0% (0.3, 3.8)	1.2% (0.3, 4.2)	2.7% (0.9, 7.4)	3.7% (1.3, 9.7)	4.4% (1.6, 11.5)	4.9% (1.8, 12.8)	6.5% (2.3, 16.9)
5	[illegible] (0.4, 7.9)	4.4% (1.7, 11.0)	5.0% (2.0, 11.8)	9.3% (4.7, 17.6)	12% (6, 21)	14% (7, 24)	15% (8, 26)	18% (9, 32)
10	3.3% (0.8, 12.6)	7.4% (3.1, 16.5)	8.3% (3.8, 17.5)	14% (8, 24)	18% (10, 29)	20% (12, 32)	22% (13, 35)	26% (15, 41)
15	4.5% (1.2, 16.2)	9.8% (4.3, 20.7)	11% (5, 22)	18% (11, 29)	22% (14, 34)	25% (15, 37)	27% (16, 40)	31% (19, 47)
20	5.7% (1.5, 19.2)	12% (5, 24)	13% (6, 25)	21% (13, 33)	26% (16, 38)	28% (18, 41)	30% (19, 44)	35% (22, 51)
25	6.7% (1.8, 21.8)	14% (6, 27)	15% (7, 28)	24% (15, 36)	28% (18, 41)	31% (20, 45)	33% (22, 47)	38% (25, 54)
40	[illegible] (2.7, 27.8)	18% (9, 33)	20% (10, 35)	30% (19, 43)	35% (23, 48)	38% (25, 52)	40% (27, 54)	45% (31, 61)
55	12% (3, 32)	21% (10, 38)	23% (12, 40)	34% (22, 48)	39% (27, 53)	42% (29, 57)	45% (31, 59)	50% (35, 65)
70	13% (4, 36)	24% (12, 42)	26% (14, 44)	37% (24, 52)	43% (29, 57)	46% (32, 60)	48% (34, 63)	54% (38, 69)
100	17% (5, 41)	28% (14, 48)	31% (16, 49)	43% (28, 58)	48% (34, 63)	51% (37, 66)	54% (39, 68)	59% (43, 73)

[a]All other variables held at their national median.

[b]Estimated median levels based on U.S. Housing and Urban Development national survey, 1989–1990.

TABLE 6

Likelihood of a Child's Blood Lead ≥ 15 μg/dL for Floor Dust Lead Loadings and Exterior Exposure Levels (ppm)[a]

Dust lead loading (μg/ft²)	Probability of blood lead greater than 15 μg/dL							
	Exterior lead exposure (ppm)							
	10	72[b]	100	500	1000	1500	2000	4000
1	0.027% (0.002, 0.319)	0.11% (0.02, 0.63)	0.13% (0.02, 0.72)	0.37% (0.09, 1.52)	0.55% (0.14, 2.17)	0.70% (0.18, 2.70)	0.82% (0.21, 3.16)	1.2% (0.3, 4.6)
5	0.22% (0.03, 1.65)	0.70% (0.19, 2.60)	0.84% (0.24, 2.86)	1.9% (0.7, 4.9)	2.7% (1.1, 6.5)	3.2% (1.3, 7.7)	3.7% (1.5, 8.7)	4.9% (2.0, 11.8)
10	0.48% (0.07, 3.14)	1.4% (0.4, 4.6)	1.7% (0.5, 5.0)	3.5% (1.5, 7.9)	4.8% (2.2, 10.1)	5.6% (2.6, 11.7)	6.3% (3.0, 13.0)	8.2% (3.8, 17.0)
15	0.74% (0.12, 4.49)	2.1% (0.7, 6.3)	2.4% (0.8, 6.8)	4.9% (2.3, 10.3)	6.5% (3.2, 12.8)	7.6% (3.8, 14.7)	8.5% (4.2, 16.3)	11% (5, 21)
20	0.99% (0.17, 5.73)	2.7% (0.9, 7.8)	3.1% (1.1, 8.4)	6.1% (2.9, 12.4)	8.0% (4.1, 15.2)	9.3% (4.8, 17.2)	10% (5, 19)	13% (7, 24)
25	1.2% (0.2, 6.9)	3.2% (1.1, 9.2)	3.7% (1.4, 9.8)	7.2% (3.5, 14.2)	9.3% (4.9, 17.2)	11% (6, 19)	12% (6, 21)	15% (8, 26)
40	1.9% (0.4, 9.9)	4.7% (1.7, 12.8)	5.4% (2.1, 13.5)	10% (5, 19)	13% (7, 22)	14% (8, 25)	16% (9, 27)	19% (11, 32)
55	2.6% (0.5, 12.5)	6.1% (2.2, 15.8)	6.9% (2.7, 16.6)	12% (6, 22)	15% (9, 26)	17% (10, 29)	19% (11, 31)	23% (13, 37)
70	3.2% (0.6, 14.7)	7.2% (2.6, 18.3)	8.2% (3.3, 19.2)	14% (8, 25)	18% (10, 29)	20% (11, 32)	21% (13, 34)	26% (15, 40)
100	4.3% (0.9, 18.6)	9.3% (3.5, 22.6)	10% (4, 24)	18% (9, 30)	21% (12, 35)	24% (14, 37)	26% (15, 40)	30% (18, 46)

[a] All other variables held at their national median.

[b] Estimated median levels based on U.S. Housing and Urban Development national survey, 1989–1990

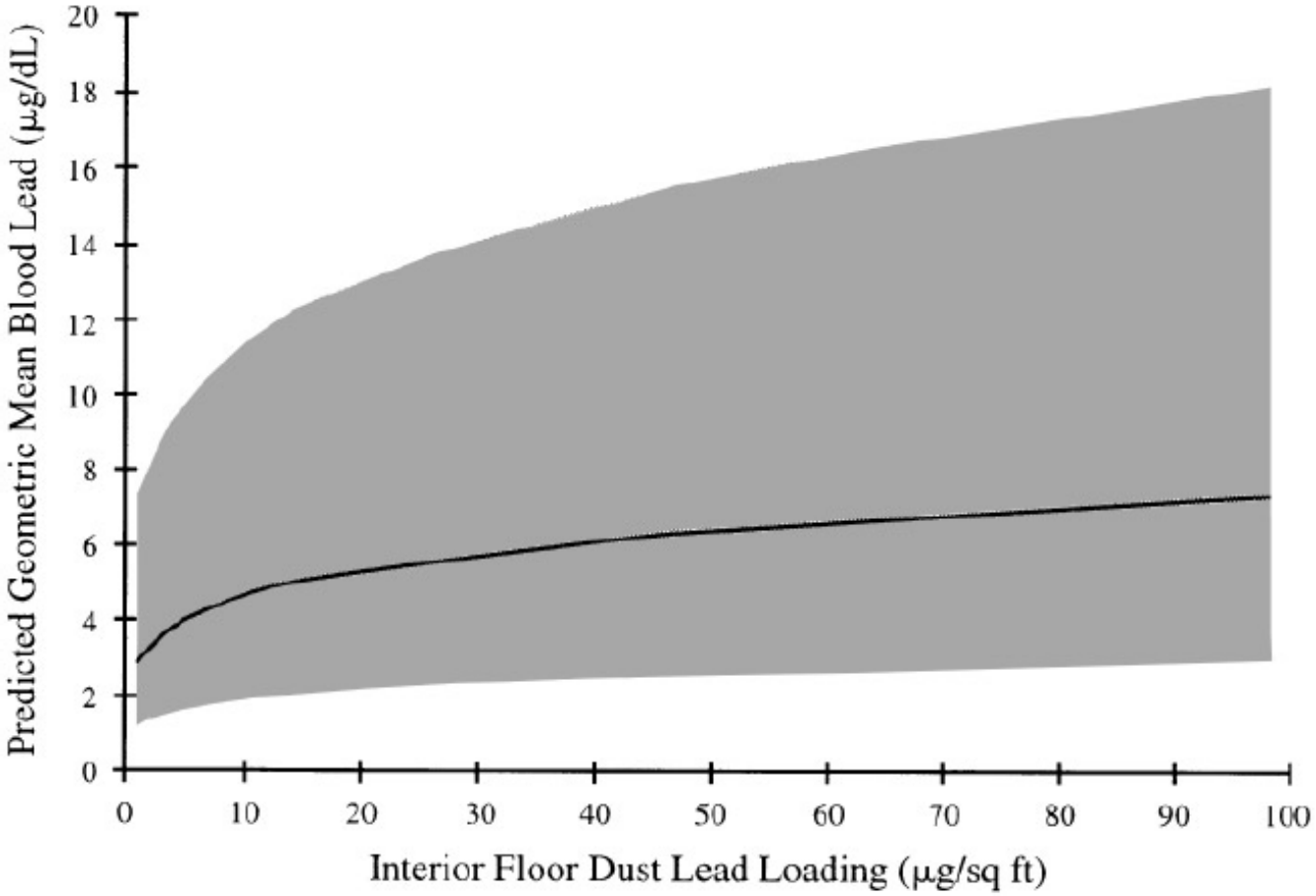

Predicted Geometric Mean Blood Lead (µg/dL)
0
2
4
6
8
10
12
14
16
18
20
0
10
20
30
40
50
60
70
80
90
100
Interior Floor Dust Lead Loading (µg/sq ft)

TABLE 6

Likelihood of a Child's Blood Lead ≥ 15 µg/dL for Floor Dust Lead Loadings

Dust lead loading (µg/ft²)	10	72[b]
1	0.027% (0.002, 0.319)	0.11% (0.02, 0.63)
5	0.22% (0.03, 1.[illegible])	0.70% (0.19, 2.60)
10	[illegible] (0.07, 3.[illegible])	1.4% (0.4, 4.6)
15	0.74% (0.12, 4.49)	2.1% (0.7, 6.3)
20	0.99% (0.17, 5.73)	2.7% (0.9, 7.8)
25	1.2% (0.2, 6.9)	3.2% (1.1, 9.2)
40	[illegible] (0.4, 9.9)	4.7% (1.7, 12.8)

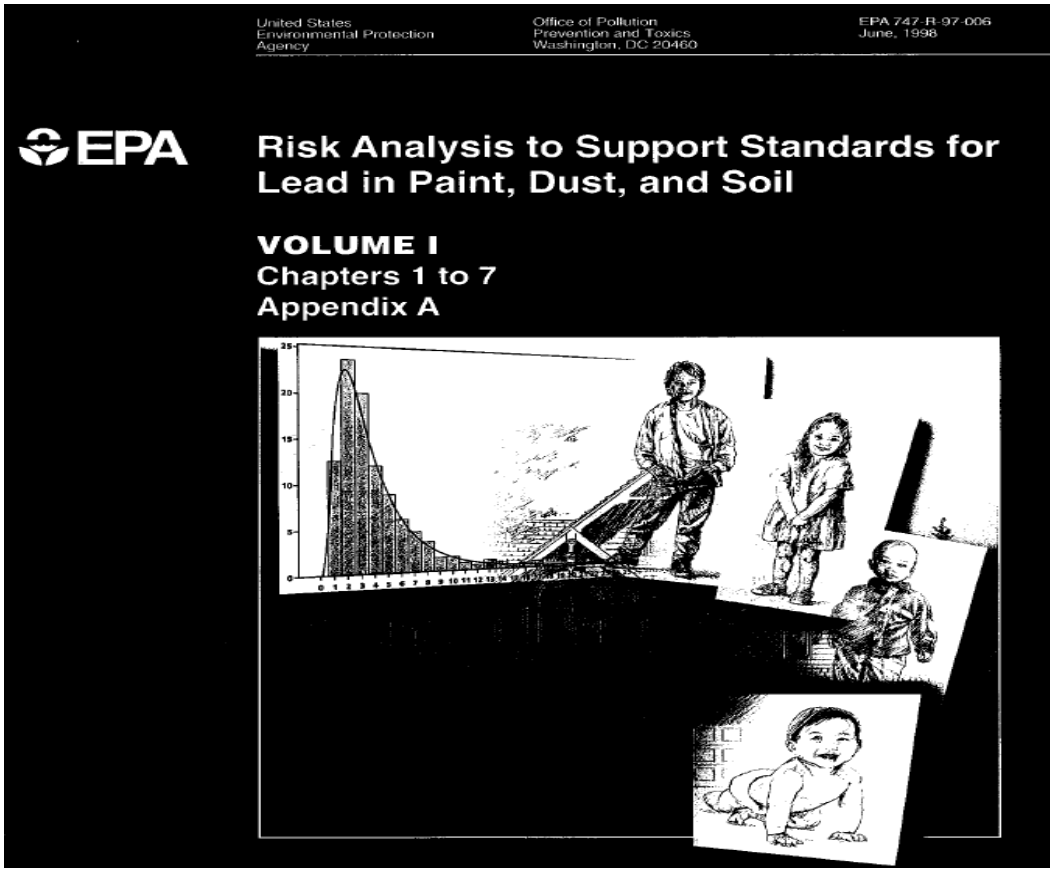
TABLE 5

Likelihood of a Child's Blood Lead ≥ 10 μg/dL for Floor Dust Lead Loadings

Dust lead loading (μg/ft²)	10	72[b]
1	0.33% (0.05, 2.24)	1.0% (0.3, 3.8)
5	1.8% (0.4, 7.9)	4.4% (1.7, 11.0)
10	4.0% (0.8, 12.6)	7.4% (3.1, 16.5)
15	4.5% (1.2, 16.2)	9.8% (4.3, 20.7)
20	5.7% (1.5, 19.2)	12% (5, 24)
25	6.7% (1.8, 21.8)	14% (6, 27)
40	9.8% (2.7, 27.8)	18% (9, 33)

Existing PbD Standard

- Existing standard protects 95% of children from developing a PbB> 15 µg/dL (from pooled analysis of high risk houses)
- In 1997, average lab reporting limit was about 25 µg/wipe (using flame AAS)
- Typically regulatory stds are set at least 3 to 10 times above detection limits, to ensure reliability of measurements



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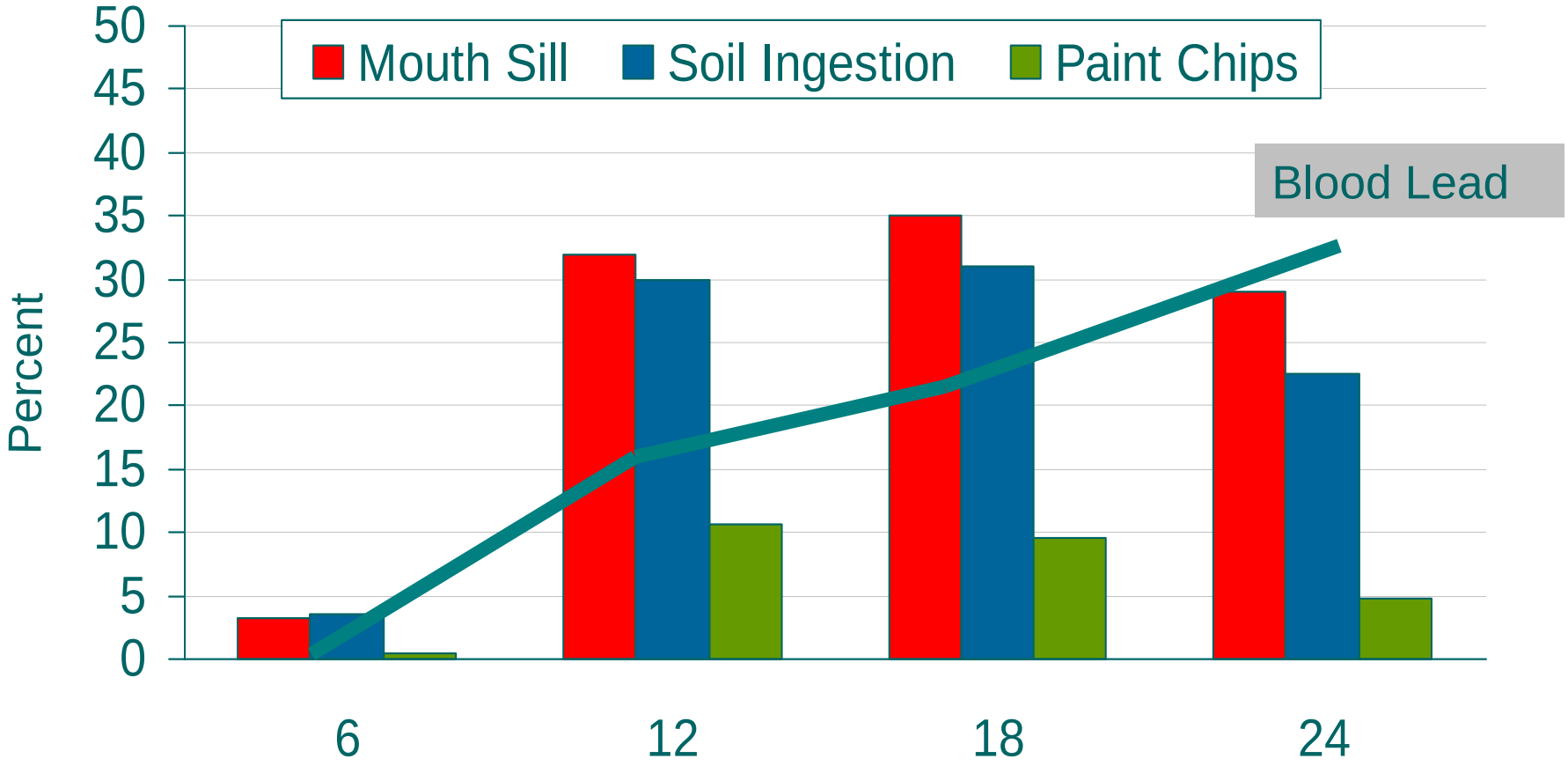
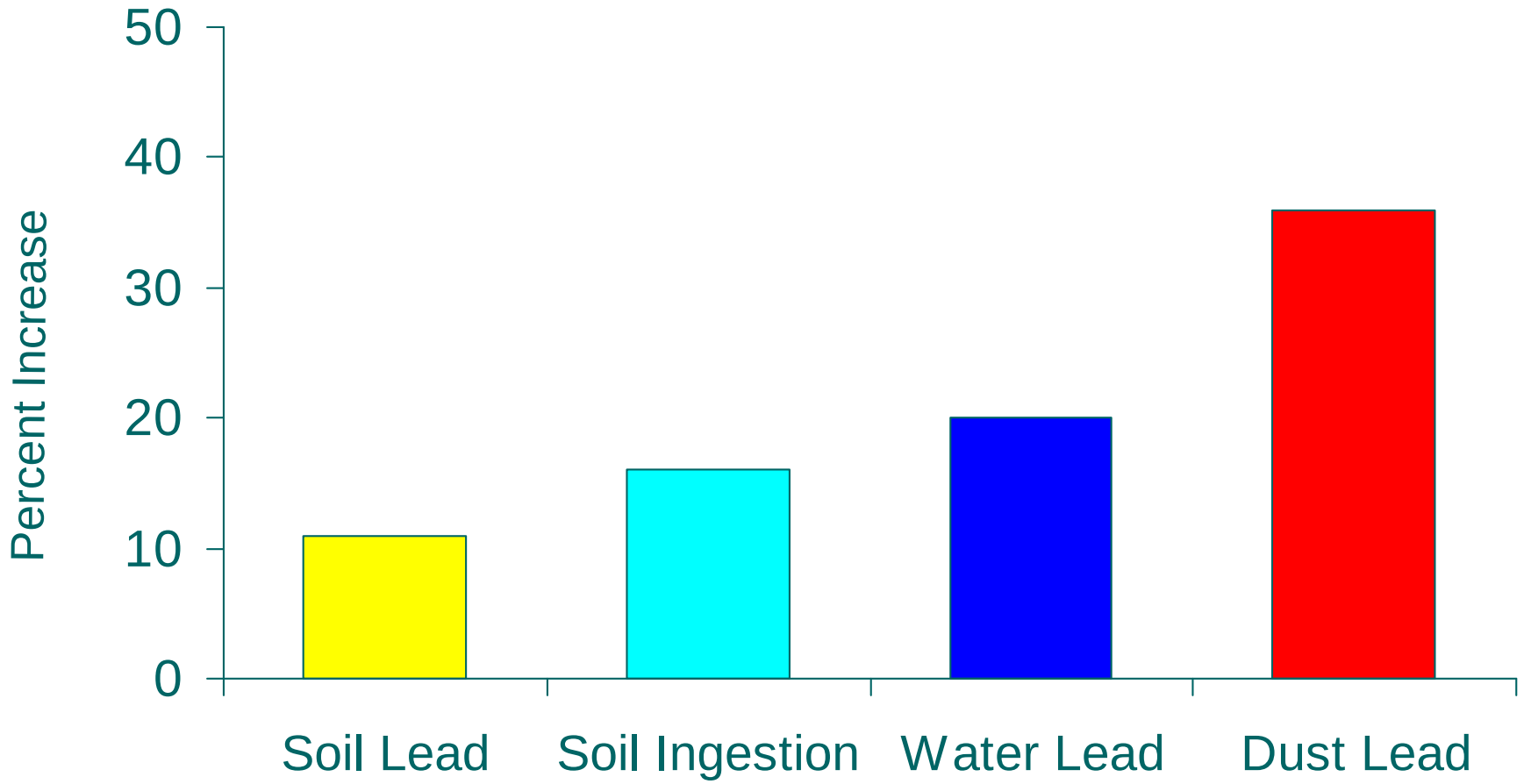
Frequency of Mouthing Behaviors during Early Childhood and Blood Lead Levels



Lanphear BP. Journal of Pediatrics 2002;140:40-47

Sources of Lead Exposure during Early Childhood



Lanphear BP, et al. Journal of Pediatrics 2002;140:40-47.

Summary of Evidence: Why A New Dust Standard Is Needed

New Data (Cross-Sectional)

- **HUD National Survey (2000)**
  - Floor GM = 1 µg/ft^2
  - 90th percentile (floor) < 10 µg/ft^2
- **NHANES/PbD Analysis (2008)**
  - 98% of homes have floor PbD <10 µg/ft^2

New Data (Longitudinal) Floor Dust Lead (µg/ft^2)

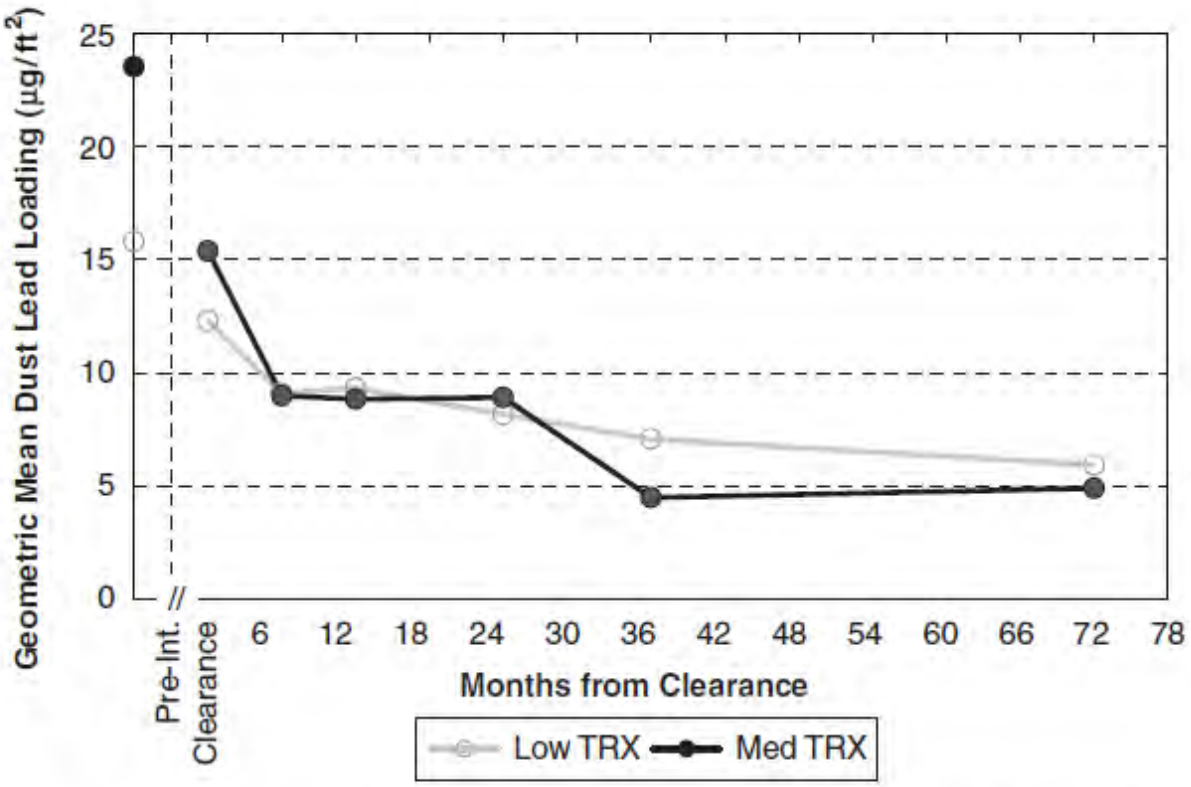
Study	GM	90th %
Cinci HOME Baseline	1.4	11.2
Cinci HOME One Year	1.2	6.9
HUD Baseline	21.5	142
HUD Six Year	4.8	32

New Data (Longitudinal)
Sill Dust Lead (µg/ft²)

Study	GM	90th %
Cinci HOME Baseline	28	988*
Cinci HOME One Year	9.3	131*
HUD Baseline	239	2,598
HUD Six Year	73	837

Six-Year Followup of HUD Evaluation Study

(Wilson et al. 2006. Env Res 102: 237-248)



Geometric mean floor dust lead levels from pre-intervention through 6 years post-clearance, by treatment level.

Repair & Maintenance Study

- Large reductions (76% to 99%) in Floor PbD two years after intervention

Farfel et al. 1997. Lead-based paint abatement and repair and maintenance study in Baltimore: Findings based on two years of follow-up. EPA Report 747-97-005

NCHH Risk Assessment Study

Study of HUDs
Risk Assessment
Methodology in
Three U.S. Communities

Final Report

Prepared for:
The U.S. Department of Housing and Urban Development
Office of Healthy Homes and Lead Hazard Control

By
The National Center for Healthy Housing

Volume I
Main Report and
Appendix A
January 24, 2003
Revised: June 30, 2006

NCHH Risk Assessment Study

Table 6.1.5a: Performance Characteristics for Nine Optimal Dust Sampling Protocols (Milwaukee) (n=64) [1]

#	Protocol	Percent Failure	Test of Independence P-Value	Performance Characteristic (95% CI)			
				Sensitivity	Specificity	Positive Predictive Value	Negative Predictive value
Dust Protocol/Standards (µg/ft2)							
1	Floor 5	83	0.006	97 (83,100)	30 (16,49)	57 (42,70)	91 (59,100)
2	Floor (w/Entry), Sill 10, 250	80	0.012	94 (79,99)	33 (18,52)	57 (42,71)	85 (55,98)
3	Floor (w/Entry) 10	70	0.001	90 (74,98)	48 (31,66)	62 (47,76)	84 (60,97)
4a	Floors 10	55	0.014	71 (52,86)	61 (42,77)	63 (45,79)	69 (49,85)
4b	Floor (w/Entry) 15	55	0.014	71 (52,86)	61 (42,77)	63 (45,79)	69 (49,85)
5	Floor (w/Entry) 20	44	0.043	58 (39,75)	70 (51,84)	64 (44,81)	64 (46,79)
6	Floor (w/Entry) 25	31	0.030	45 (27,64)	82 (65,93)	70 (46,88)	61 (45,76)

Measurement

- Reporting limit today is 3 µg/wipe
  - (Cossa 2007, personal communication)
- Lower reporting limits feasible
  - AAS, ICP, Graphite Furnace

Window Sill PbD from NHANES

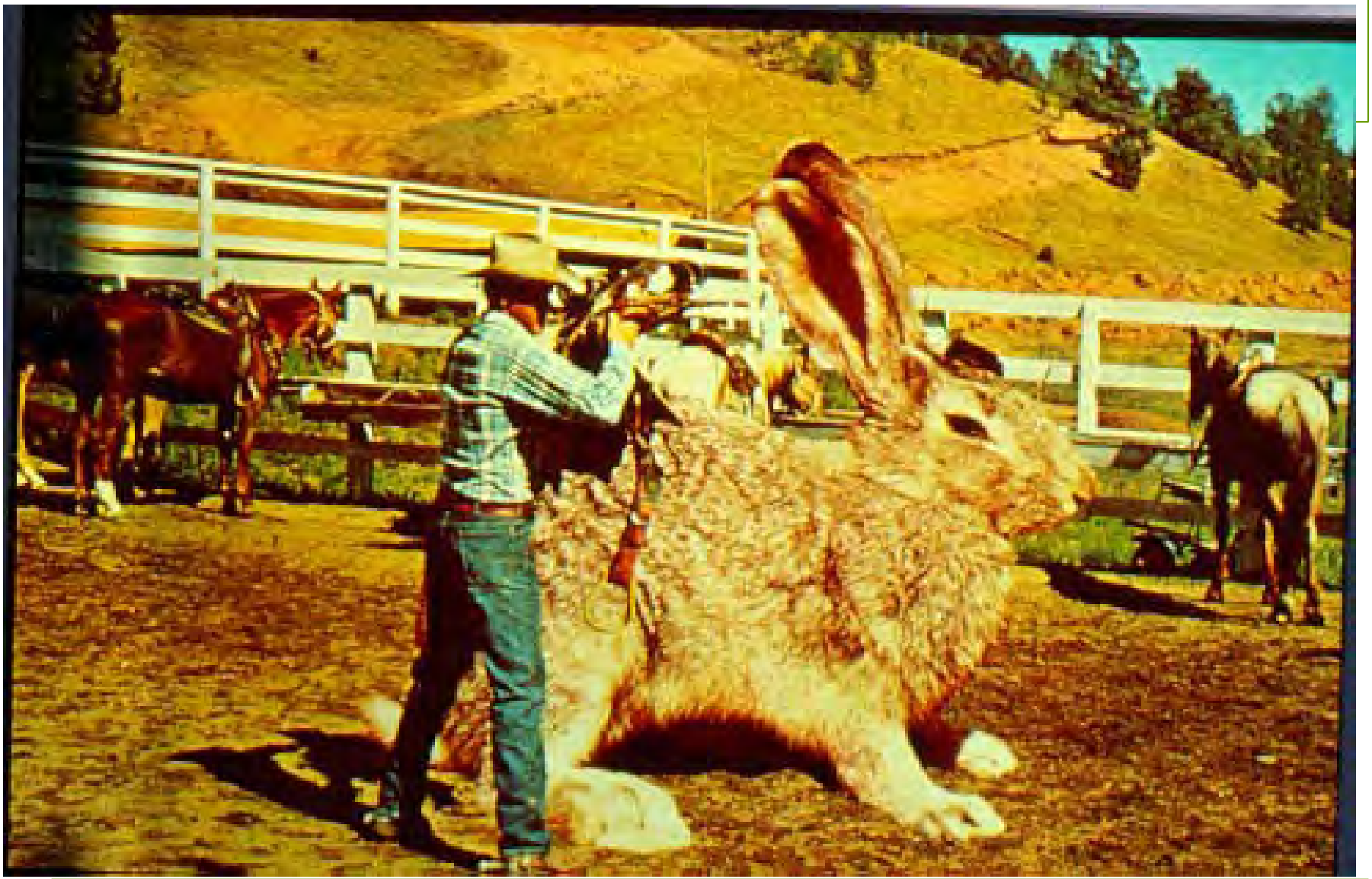
- If Floor PbD = 10 µg/ft^2
- Then Sill PbD = 100 µg/ft^2

A Dust Lead Standard of <10 µg/ft² (floors) and <100 µg/ft² (sills)

- **Protective** – Vast majority (>95%) of children will have PbB < 10 µg/dL
- **Measurable** - 3 times greater than lab detection limit (Flame AAS)
- **Feasible** – Long-term studies show most houses can comply using existing lead cleaning methods
- **Not A Burden** – New evidence is that > 90% of pre-1978 homes are:
  - < 10 µg/ft² (floors)
  - < 100 µg/ft² (sills)

Recommendations

- EPA should revise the standard
- EPA should be required to periodically review the science, as it does for NAAQS and other lead standards;
- PbD should be kept as low as possible
- Parents, contractors, risk assessors and others should keep Floor PbD <10 µg/ft^2 and Sill PbD <100 µg/ft^2 immediately
- Local jurisdictions should consider adopting the NCHH recommended standard
- **We should act on what the science tells us!**



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Acknowledgments, Disclaimers and Contact Information

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BUILDING A FRAMEWORK FOR HEALTHY HOUSING

2008 National Healthy Homes Conference

Evaluation of the Effectiveness of the Milwaukee Lead Hazard Control Ordinance:

Overview and How the Results can Inform Options for Lowering Dust Lead Standards

Peter J. Ashley, DrPH
HUD Office of Healthy Homes and Lead Hazard Control
September 16, 2008

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Elizabeth Slone

Rona Boehm

*Darlene Wells

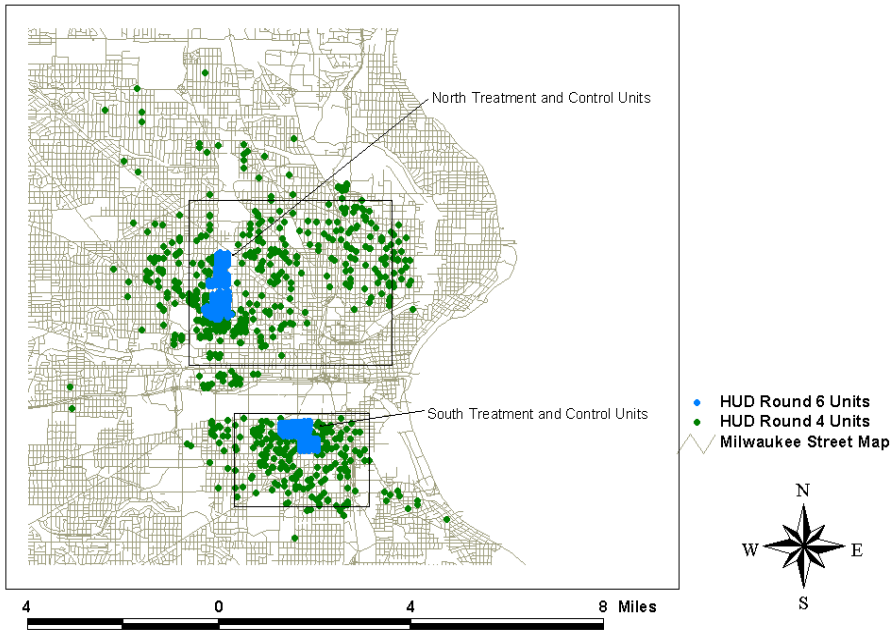
*Jyothi Nagaraja

*Dale Rhoda

*Added for Pb standard analysis

The Milwaukee Ordinance

- Enacted in 1999
- Required property owners of pre-1950 rental properties in two high-risk neighborhoods to implement standard treatments between May 1, 1999 and April 30, 2000

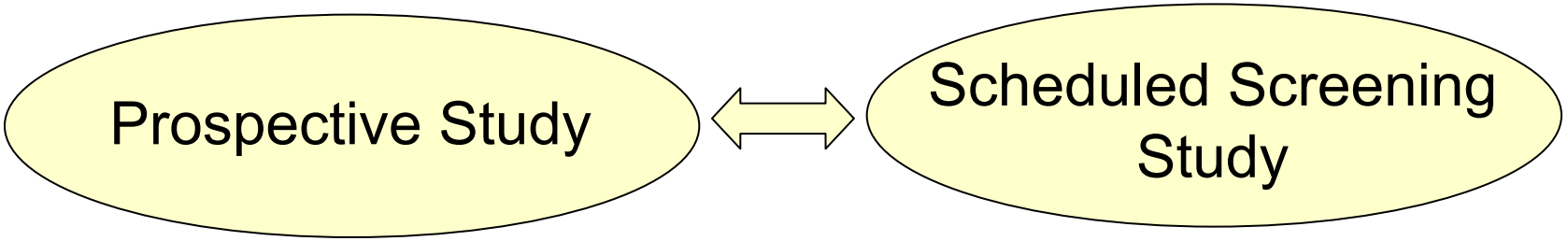


- Approximately 1,000 target housing units with an estimated 750 children under 6 in the pilot ordinance area
- In 1997, 59% of children 6-36 months in North neighborhood and 29% in South neighborhood had blood lead levels ≥ 10 µg/dL

Original Study Objectives

- Characterize the effectiveness of treatments in reducing lead exposure in children living in high risk housing when followed prospectively from ages 6-24 months.
- Characterize treatment effectiveness by monitoring dust-Pb levels and physical condition over a two year period following intervention.

The Longitudinal Study Design



- Track BLLs of newborn children in treated units and dust lead levels at 6, 12, 18, and 24 months of age
  - Children's BLLs at 6, 12, 18, & 24 months, floor/sill/trough dust-wipes
  - Baseline Structural Assessment
  - Questionnaire
  - Visual Inspection

- Collect BLLs and environmental data for children in untreated units who had a blood lead test one year previously
  - Ethically unacceptable to prospectively track young children in high risk housing with known LBP hazards as "controls"
  - Collect BLLs, dust-wipes, questionnaires from children aged 18-24 months from untreated pre-1950 units in study neighborhoods

Interior Dust Lead Loadings by Phase

Descriptive Summary of Dust-Lead Concentrations

Study	Phase	Sample Size	Geometric Mean	Geometric Standard Deviation	Minimum	10th Percentile	25th Percentile	Median	75th Percentile	90th Percentile	Maximum	Exceedance Percentiles			
												>= 10 µg/ft^2	>= 20 µg/ft^2	>= 40 µg/ft^2	>= 100 µg/ft^2
Floor Dust-Lead Loadings															
Prospective	I	180	14.4	3.2	0	4	6	13	32	70	2052	58%	36%	21%	4%
	II	122	12.9	2.8	1	5	7	13	21	43	2879	60%	27%	12%	3%
	III	98	12.0	2.6	2	4	6	11	22	39	211	55%	29%	8%	3%
	IV	72	12.7	2.3	2	5	7	12	24	33	78	64%	33%	7%	0%
Sch. Scr. Phase II		232	14.4	3.2	1	4	6	13	30	78	1074	59%	34%	19%	6%
												≥ 250 µg/ft^2		≥ 500 µg/ft^2	
Window Sill Dust-Lead Loadings															
Prospective	I	180	162.5	4.1	0	29	58	162	395	1028	8139	38%		21%	
	II	122	146.8	3.4	5	35	67	136	306	761	3232	33%		16%	
	III	98	161.2	3.7	5	31	60	159	387	770	3818	38%		19%	
	IV	72	120.5	3.3	19	29	49	96	273	564	2550	25%		13%	
Sch. Scr. Phase II		232	557.7	5.1	16	75	185	499	1530	4080	124420	66%		50%	
												≥ 250 µg/ft^2		≥ 500 µg/ft^2	
Window Trough Dust-Lead Loadings															
Prospective	I	179	738.3	6.0	0	74	260	750	2400	7500	72300	64%		47%	
	II	121	591.4	5.6	0	73	230	640	1600	4700	27000	61%		45%	
	III	98	571.5	5.6	2	52	190	760	2000	5700	10000	62%		49%	
	IV	72	671.0	6.0	34	86	180	580	1800	7900	67000	60%		40%	
Sch. Scr. Phase II		225	14859.5	10.3	0	770	3910	17800	67100	270000	3450000	93%		89%	

Pearson Correlation Coefficients between Blood Lead and Dust-Lead Concentrations by Study and Phase

Study	Phase	Blood vs. Floor	Blood vs. Sill	Blood vs. Trough
Prospective .	I	0.221 (0.003)	0.105 (0.155)	0.145 (0.05)
	II	0.237 (0.008)	0.27 (0.002)	0.047 (0.605)
	III	0.433 (<0.001)	0.226 (0.022)	0.12 (0.229)
	IV	0.445 (<0.001)	0.214 (0.065)	0.043 (0.716)
Scheduled Screening Phase II		0.317 (<0.001)	0.348 (<0.001)	0.228 (0.001)

- Positive correlation between **floor dust lead levels** and BLLs at all phases and both studies
- Significant positive correlation between window components and BLLs in SS study, and selected phases of Prospective study

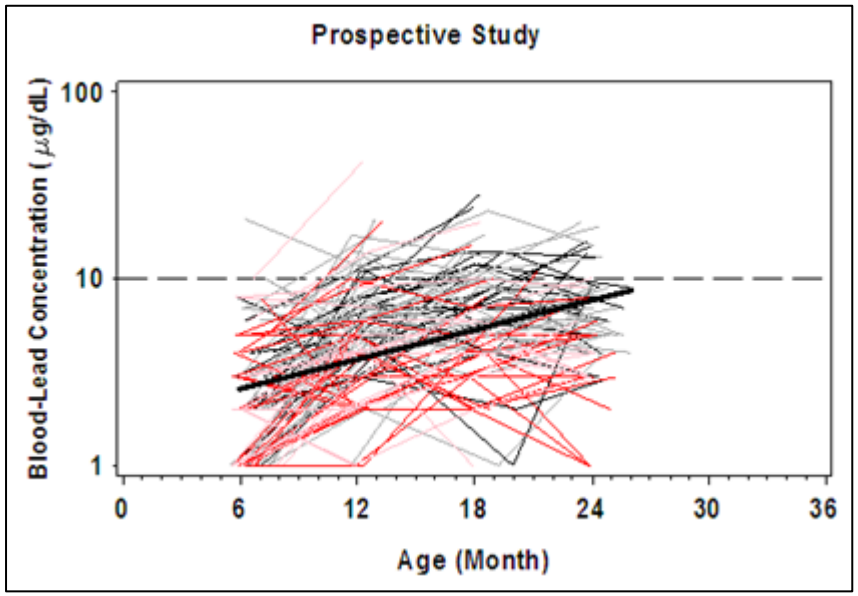
Blood Lead Concentrations by Phase

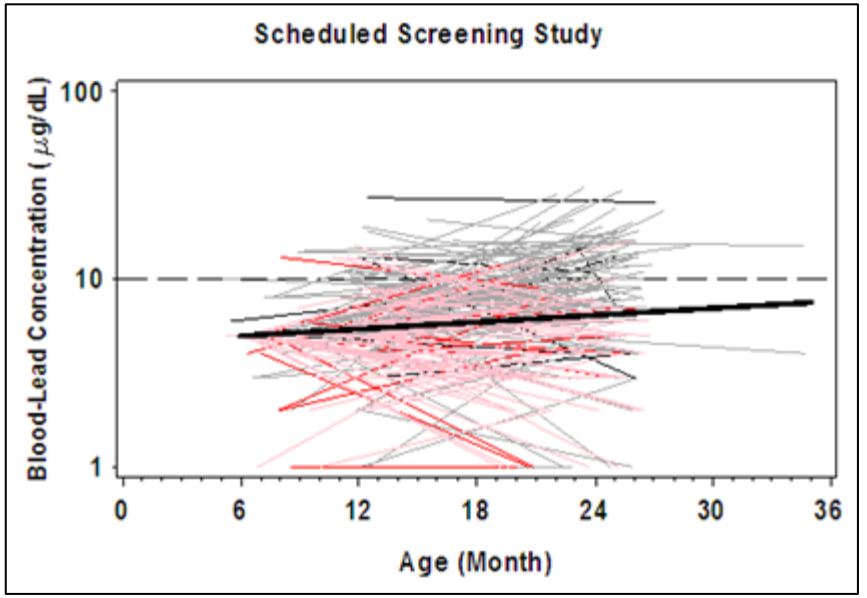
Study	Phase	Sample Size	Geometric Mean	Geometric Standard Deviation	Minimum	10th Percentile	25th Percentile	Median	75th Percentile	90th Percentile	Maximum	Exceedance Percentiles		
												>= 5 µg/dL	>= 10 µg/dL	>= 15 µg/dL
Prospective	I	185	2.49	2.10	1	1	1	2	4	7	24	25%	4%	1%
	II	126	**4.67**	1.93	1	2	3	5	7	11	42	55%	**12%**	4%
	III	102	5.87	1.94	0	3	4	5.5	10	14	28	70%	26%	7%
	IV	75	**5.62**	1.84	1	3	4	6	9	13	20	67%	**13%**	**7%**
Scheduled Screening	I	235	**5.38**	1.64	0	4	5	5	6	10	27	84%	**12%**	3%
	II	235	**6.33**	2.02	0	3	4	6	10	15	31	74%	**27%**	**11%**

- GM of Phase I SS 15% higher than Phase II Prospective (5.4 vs. 4.7)
- GM of Phase II SS 13% higher than Phase IV Prospective
- Increasing trend in Prospective study children's BLLs over time
- High rate of attrition in Prospective study – only 75 children completed all four phases

Longitudinal Modeling Results

Blood Lead Levels Over Time in Prospective and Scheduled Screening Populations

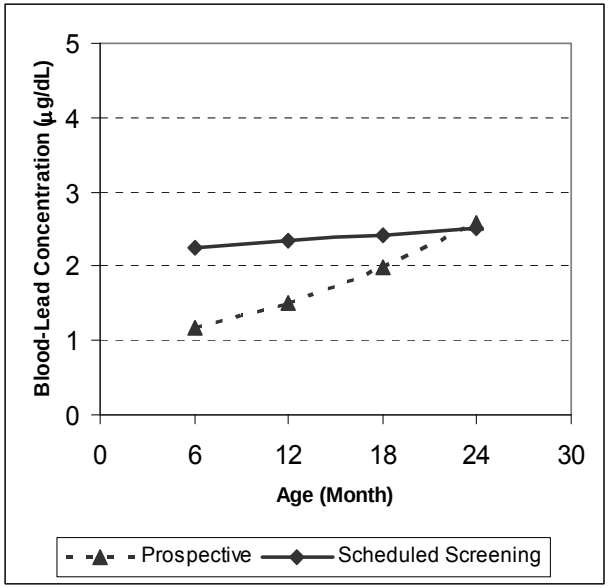




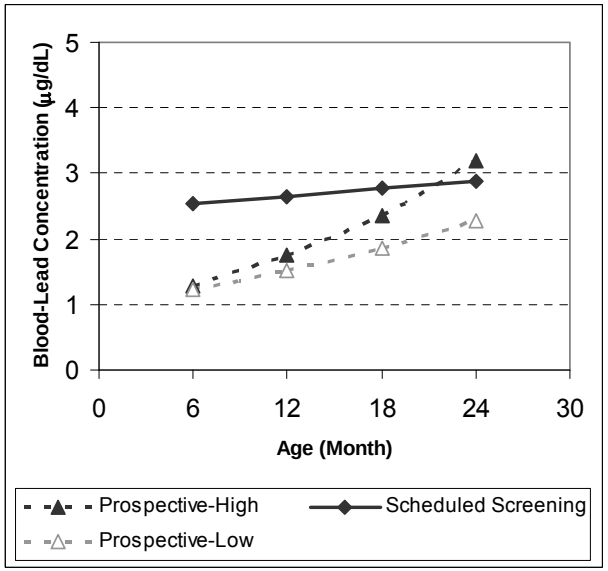
- Prospective study children had a significantly lower estimated GM blood-lead concentration at birth and higher rate of blood-lead accumulation (possibly less careful capillary blood sampling)
- Difference in estimated GM blood-lead concentration at birth was not anticipated

Modeled Changes in GM BLLs Over Time (adjusted model results)

Treated vs. Untreated



Treated vs. Untreated: Low & High Floor Dust Lead Levels



- Significant differences between treated and untreated GMs
  - 6, 12, & 18 months (PS vs. SS)
  - 6 & 12 mos. for Low and High
  - 24 mos. (base) for High and 18 mos. for Low

Significant Findings Across the Study

- Pilot ordinance was effective at reducing dust lead loadings on window sills and troughs over the 18 months they were followed

- On floors geometric mean (GM) dust lead levels and % of dwellings over certain thresholds were nearly identical between treated (prospective study) and untreated (S. screening) units

- No statistically sig. difference in probability of EBL between treated/untreated units although prevalence ≥ 10 and 15 µg/dL at 24 months was lower in treated vs. untreated

- Floor dust lead loading impacted treated/untreated comparison:

  - Prospective study children in homes with lower floor dust lead levels (< 20 µg/ft^2) had fewer EBLs as they got older compared to SS study

Impact of Lowering Dust Lead Standard on Milwaukee Study Data

Question: How can data from this longitudinal study inform options for lowering dust lead standards?

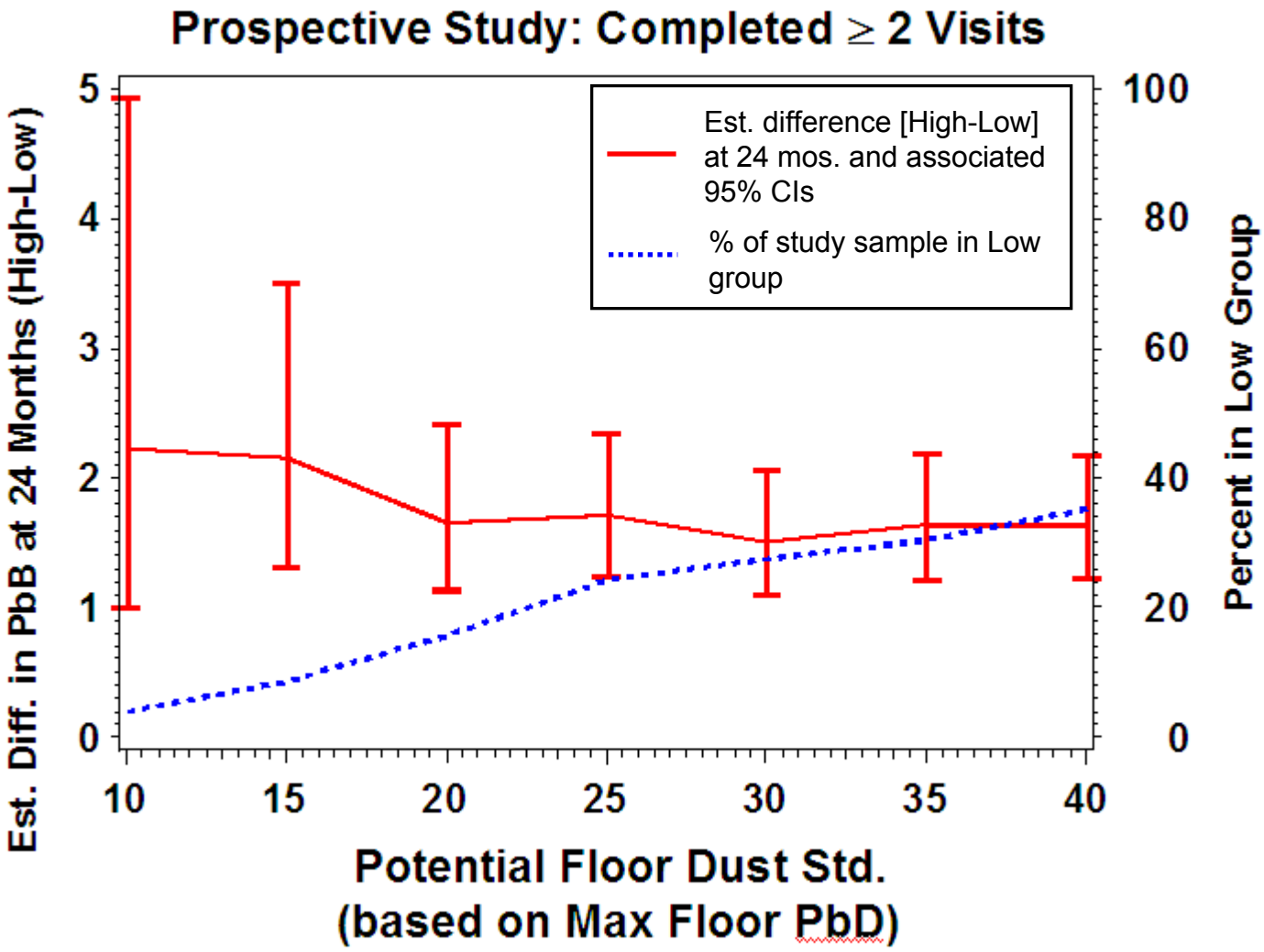
Approach:

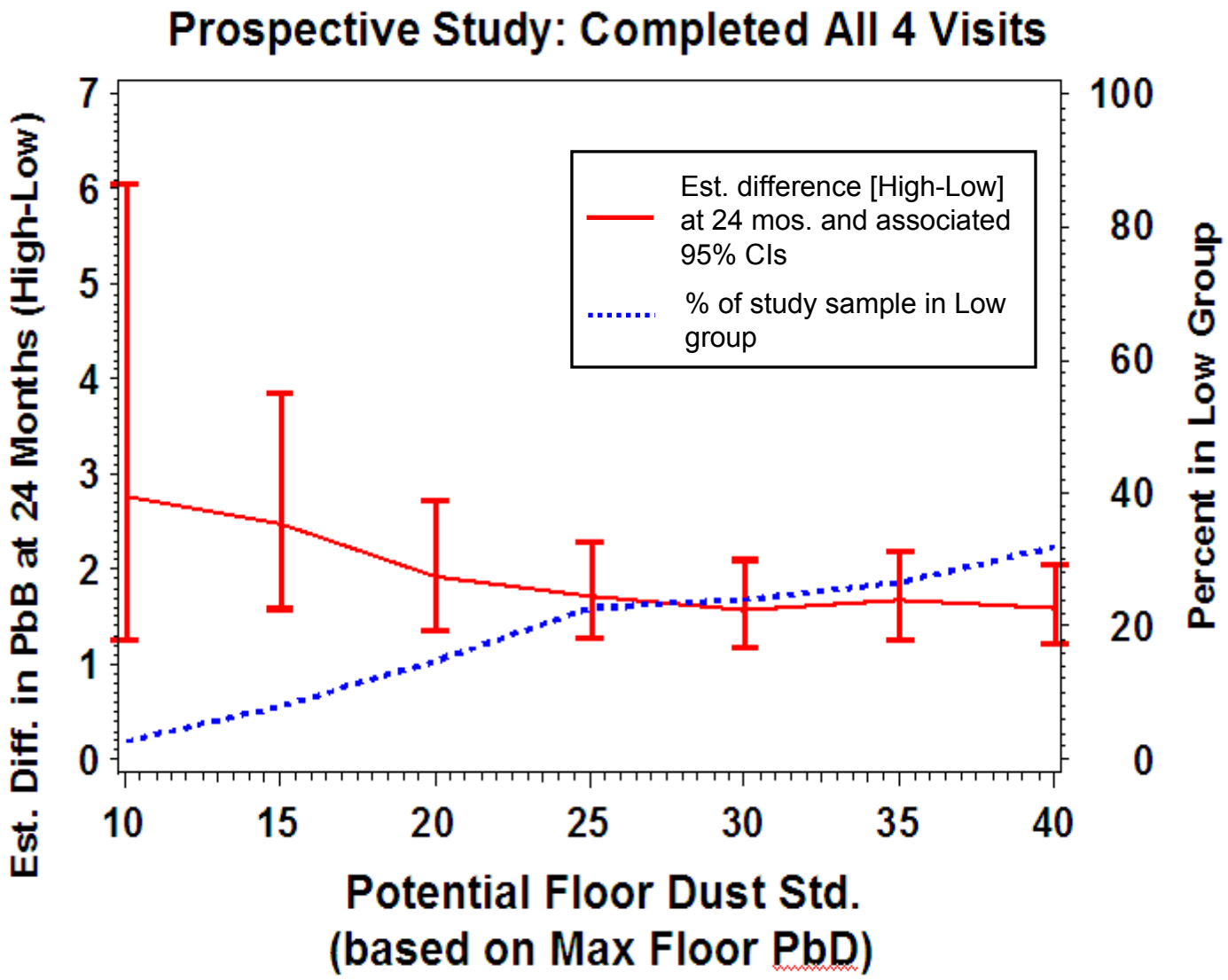
- Focus on blood lead trajectories of children in both prospective and scheduled screening studies
- Divide sample of children into high exposure group and low exposure group depending on observed dust lead levels
  - E.g., in prospective study, low group represents children whose maximum observed PbD was below 25 μg/ft^2 on floors across all sampling campaigns

Expected Results:

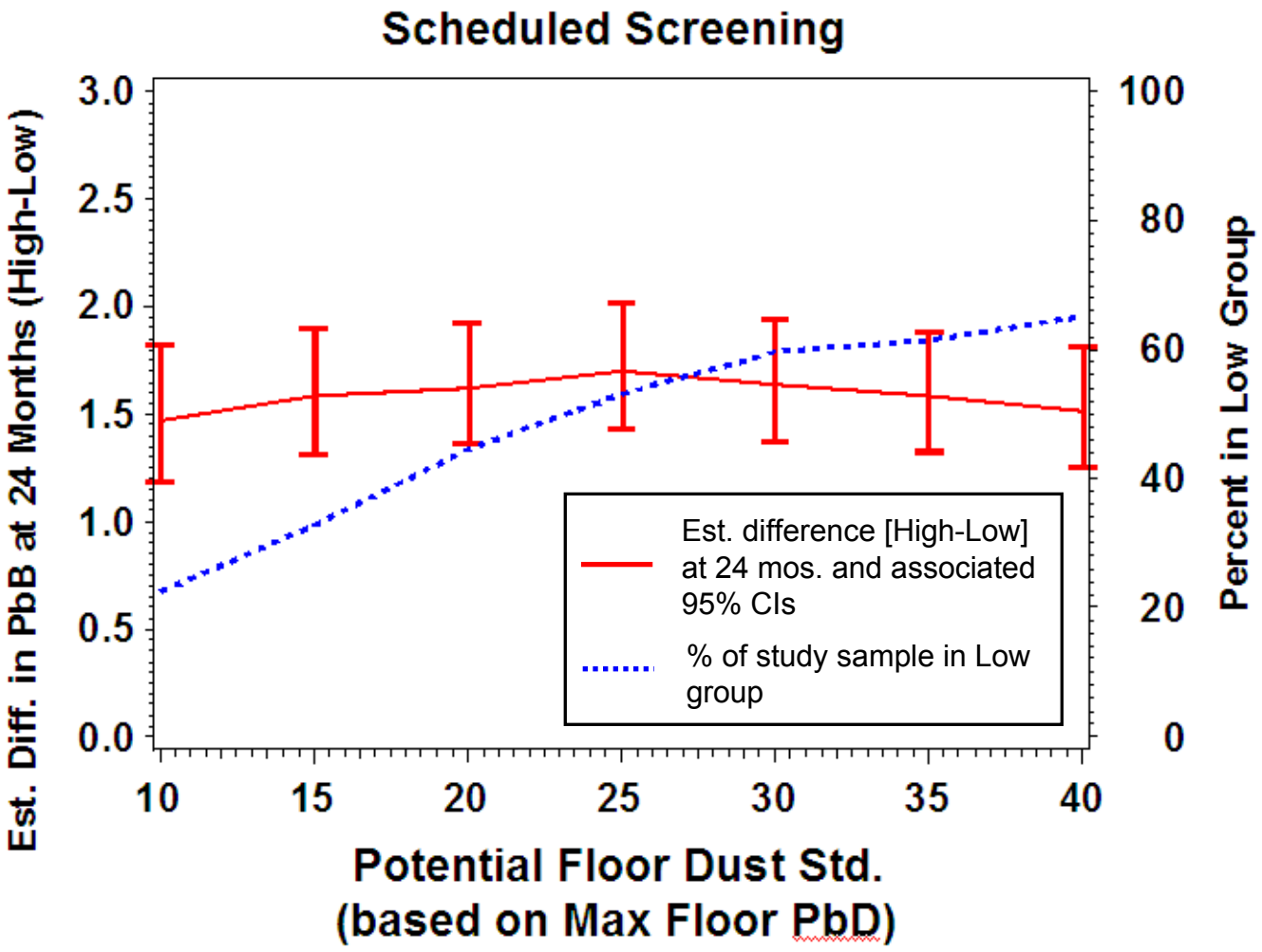
- If strong causal relationship – we expect largest differences between high and low groups for the lowest thresholds
- As threshold is lowered, fewer participants will be assigned to low group

Prospective Study, Floor Dust Lead Standard

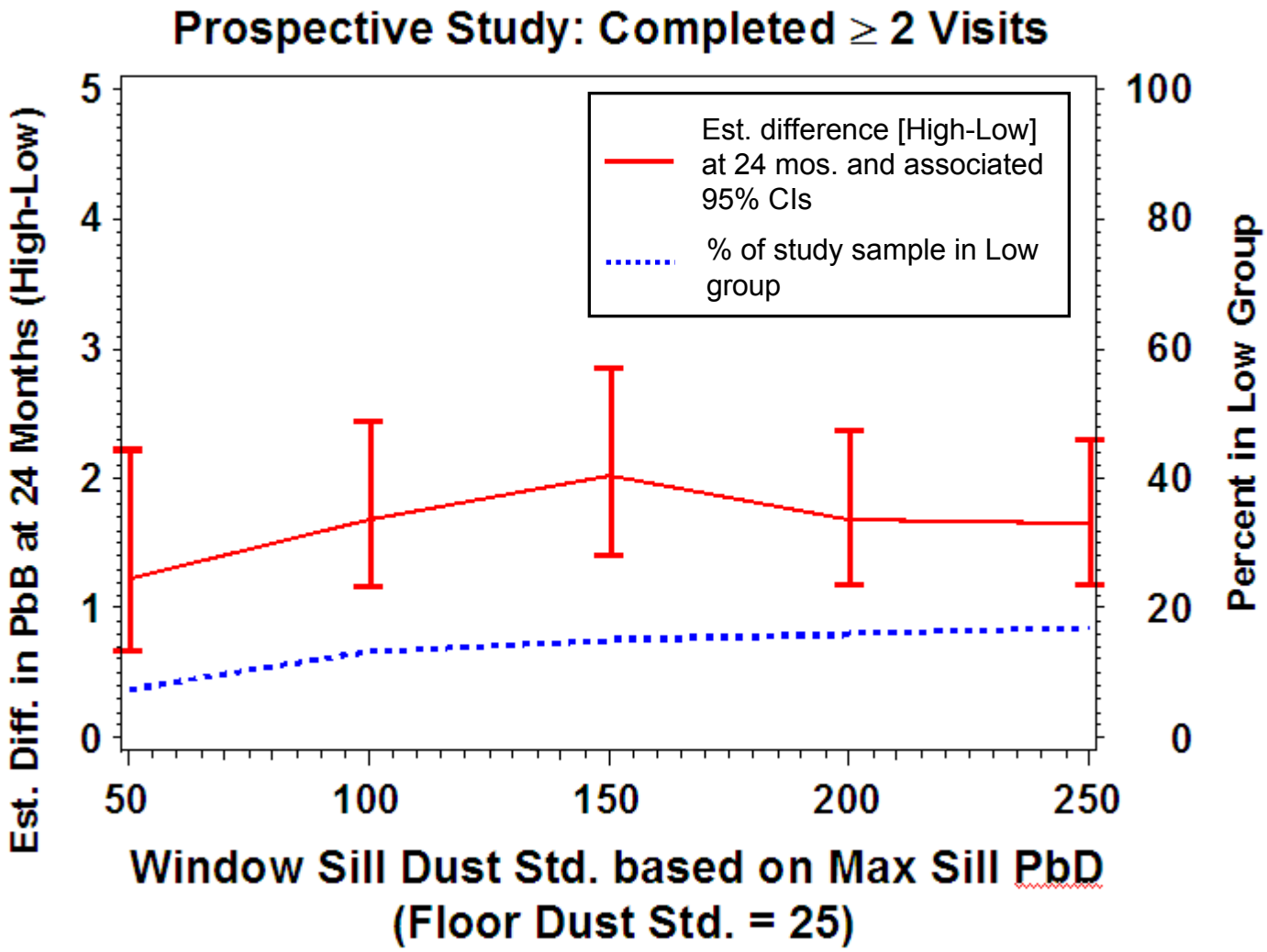


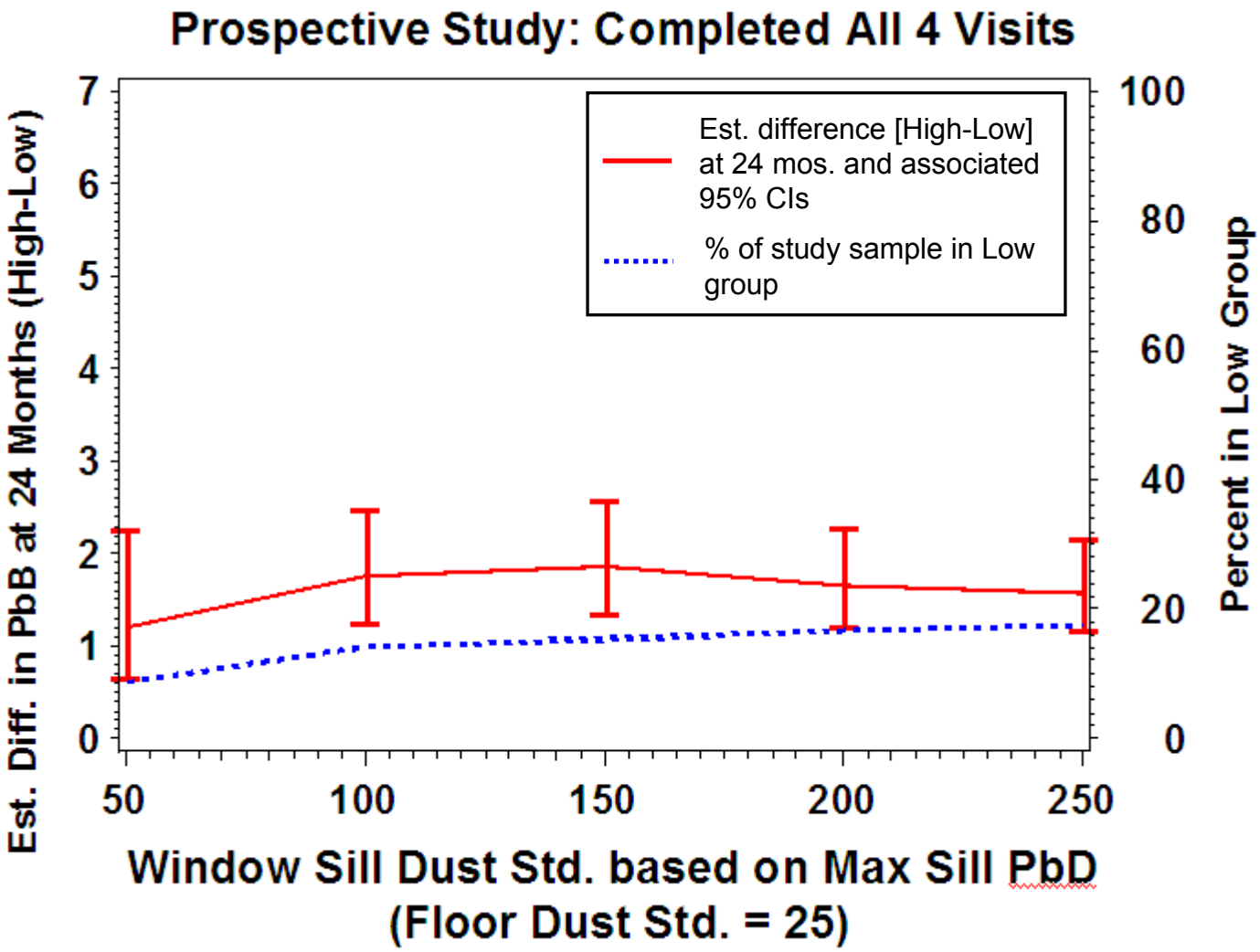

Prospective Study: Completed All 4 Visits
Est. Diff. in PbB at 24 Months (High-Low)
Percent in Low Group
Est. difference [High-Low] at 24 mos. and associated 95% CIs
% of study sample in Low group
0
1
2
3
4
5
6
7
0
20
40
60
80
100
10
15
20
25
30
35
40
Potential Floor Dust Std.
(based on Max Floor PbD)

Scheduled Screening, Floor Dust Lead Standard

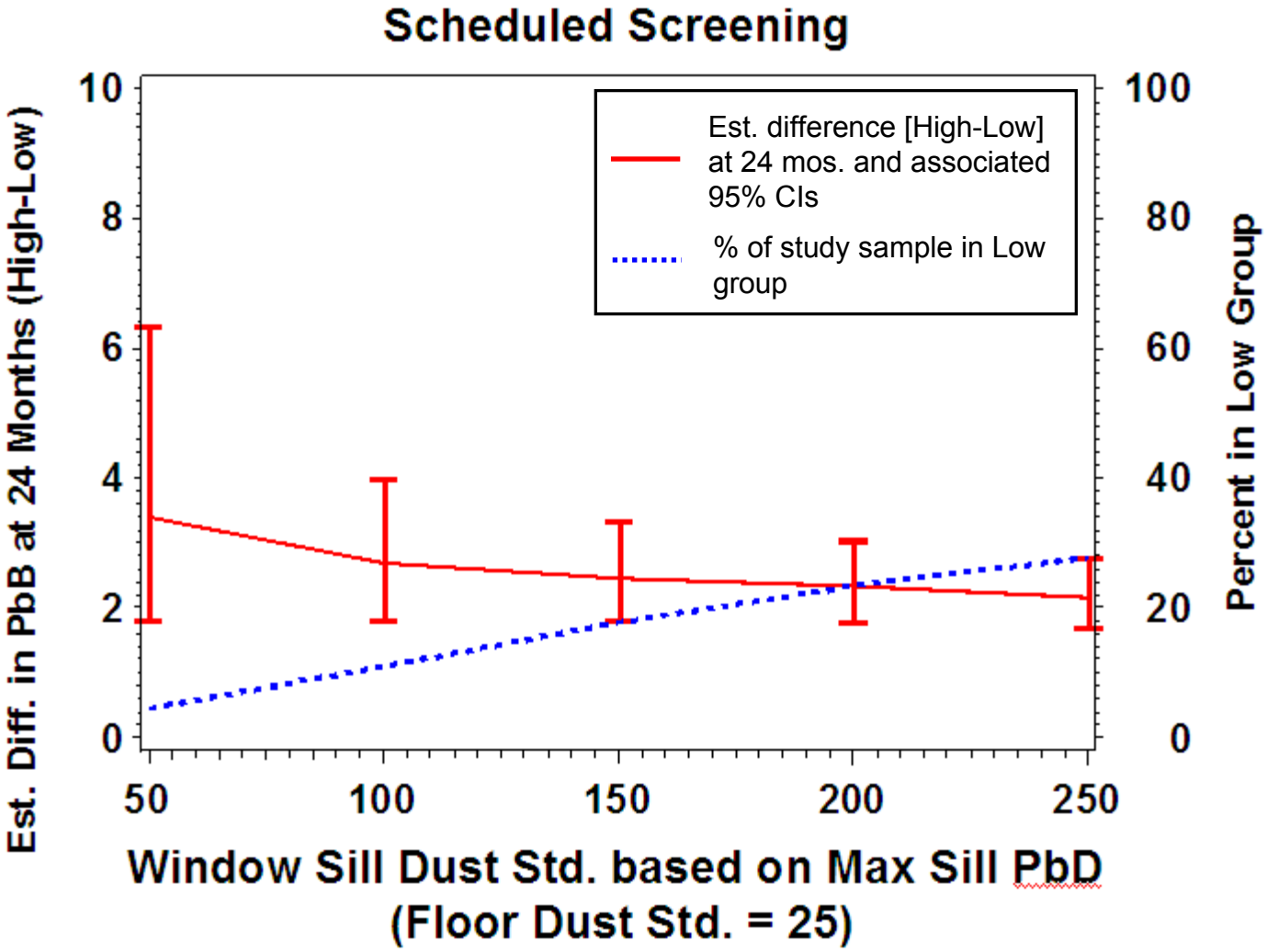


Prospective Study, Window Sill Dust Lead Standard

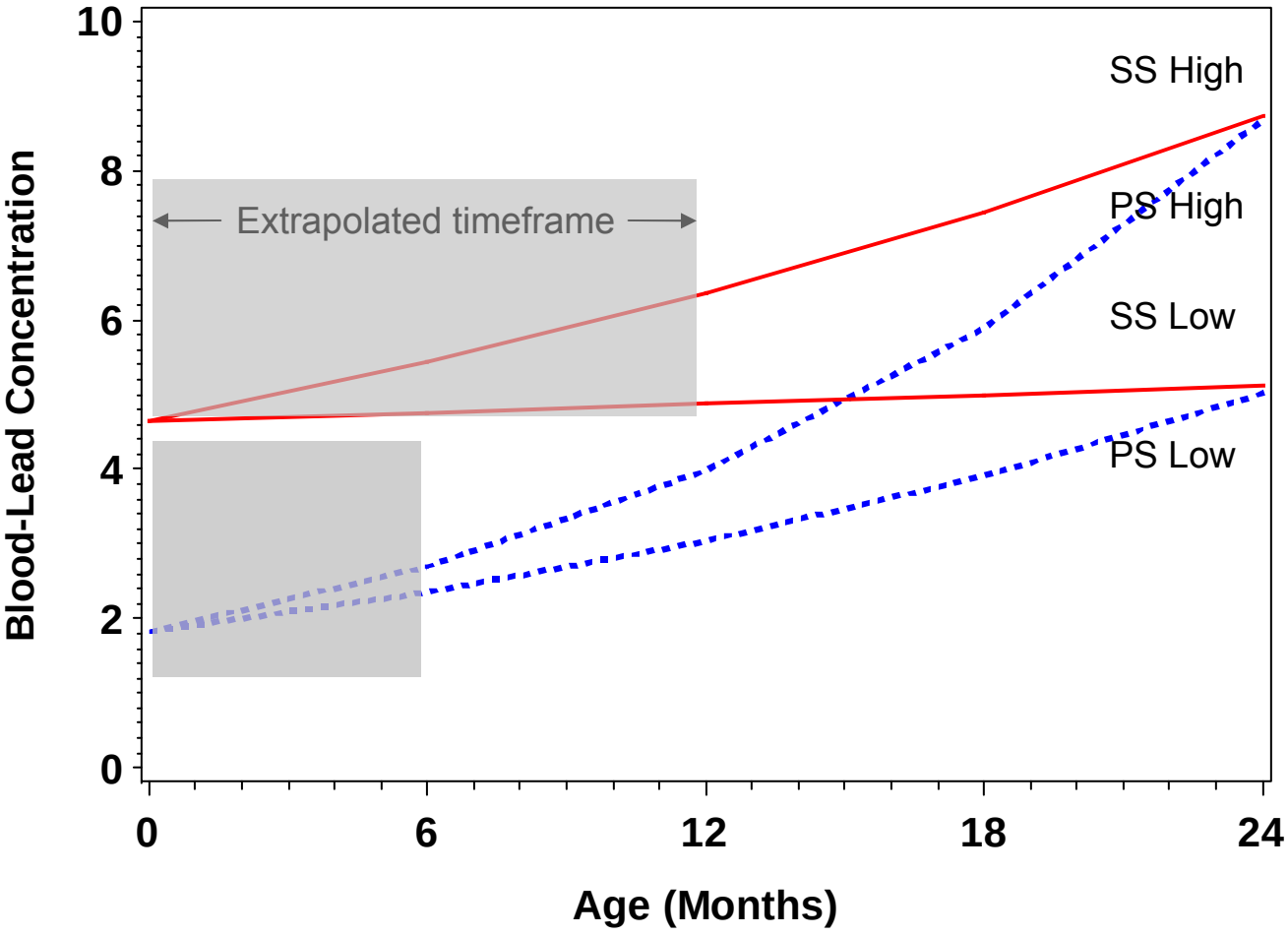



Prospective Study: Completed All 4 Visits
Est. difference [High-Low] at 24 mos. and associated 95% CIs
% of study sample in Low group
Est. Diff. in PbB at 24 Months (High-Low)
Percent in Low Group
0
1
2
3
4
5
6
7
0
20
40
60
80
100
50
100
150
200
250
Window Sill Dust Std. based on Max Sill PbD
(Floor Dust Std. = 25)

Scheduled Screening, Window Sill Dust Lead Standard



Blood Lead Trajectories for Children Living in Treated & Untreated Homes



[SS = Scheduled Study PS = Prospective Study High/Low cut-off = 25 µg/ft^2]

Conclusions

Floor Only Results:

- Prospective Study – As expected, largest group diffs. seen for lowest thresholds (supports std. < 40 µg/ ft^2)
- Scheduled Screening – not monotonically decreasing (unexpected, but units not treated, so environmental Pb exposures likely differ),
  - Also supports std. of < 40 µg/ ft^2)

Combined Floor/Window Results:

- Prospective Study – not monotonically decreasing with respect to window values
  - Supports standard < 250 µg/ ft^2 (~ 150 µg/ ft^2 in this case)
  - Recall windows were treated – perhaps causal pathway is broke for windows in treated homes
- Scheduled Screening – window relationship is monotonically decreasing (slightly), small added value of windows in addition to floors

BUILDING A FRAMEWORK FOR HEALTHY HOUSING

2008 National Healthy Homes Conference

The Contribution of Lead Dust in Housing to U.S. Children's Blood Lead Levels: New Data from NHANES 1999-2004

Sherry L. Dixon[1], Joanna M. Gaitens[2], Warren Strauss[3], Jyothi Nagaraja[3], Tim Pivetz[3], Jonathan W. Wilson[1], Peter J. Ashley[4], David E. Jacobs[1]

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Objective:

- To determine how floor dust lead loadings influence children's blood lead levels, after controlling for other housing, demographic, nutritional, smoking and other factors

National Health & Nutrition Examination Survey (NHANES) 1999-2004

- Nationally representative cross-sectional household survey
- Complex, stratified, multi-stage probability sampling design
- Tracks health of the non-institutionalized civilian U.S. population

National Health & Nutrition Examination Survey (NHANES) 1999-2004

- 1999-2004 is first time health, housing and environmental data were collected in a single integrated national survey
- Representative of the U.S. population, but not necessarily housing

Children/Homes Included:

- 2,155 children aged 12-60 months with measured blood lead and dust lead from their homes

Methods:

- Linear regression models to predict log-transformed blood lead
- Logistic regression models to predict the odds that blood lead was ≥ 5µg/dL and ≥10µg/dL

Data Considered (1)

- Laboratory
  - Blood lead
  - Serum cotinine
  - Ferritin, iron, and total iron binding capacity

Data Considered (2)

- Dust Lead
  - Floor and interior window sill dust lead from 1 room where children spent most of their time while awake
  - Typically the living room or play room.
  - Collected using standard single-surface wipe sampling method

Data Considered (3)

- Demographic
  - Age
  - Race/ethnicity
  - Gender
  - Income
  - Poverty income ratio

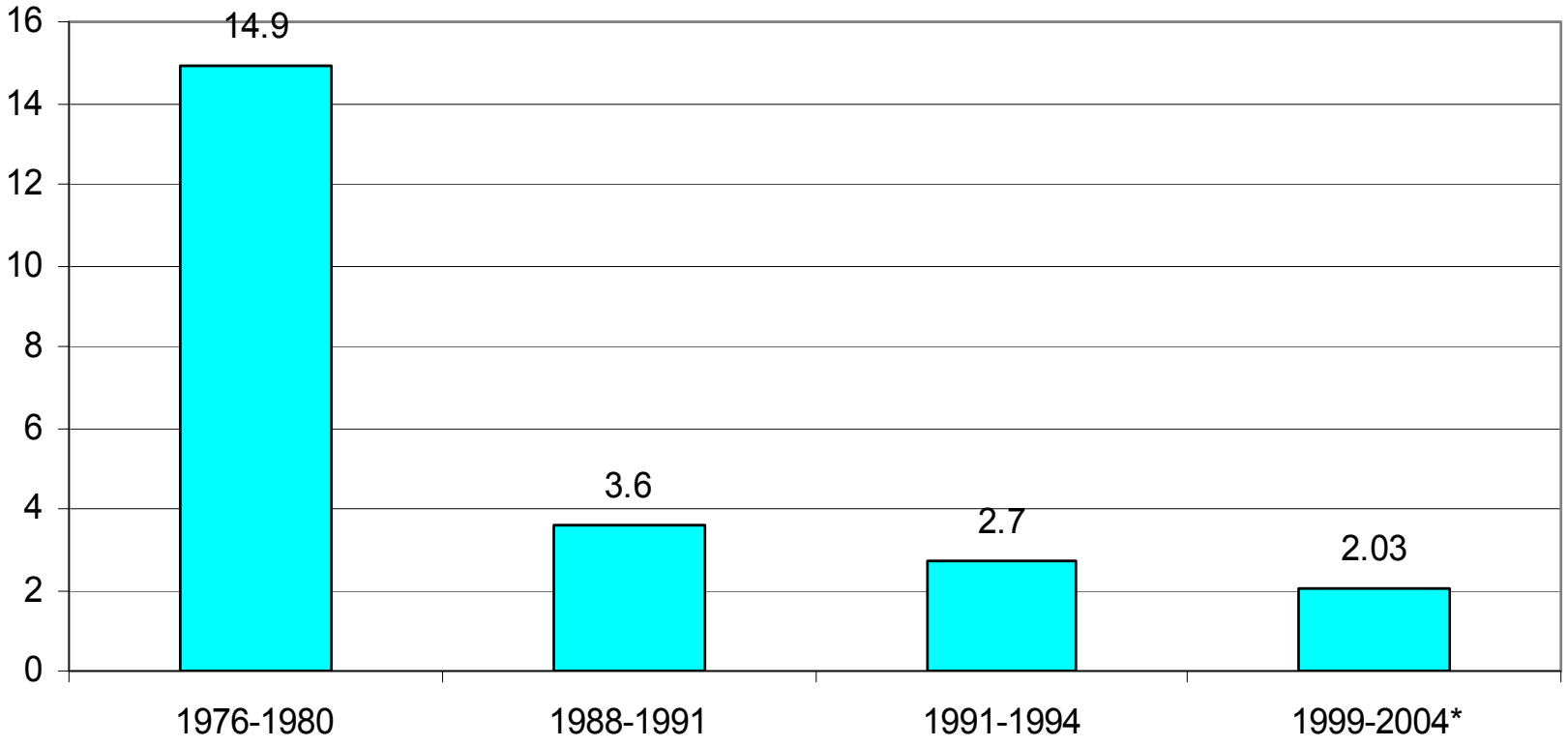
Data Considered (4)

- Smoking
  - Smoking in the home, # smokers
  - # cigarettes, cigars or pipes smoked in the home per day
- Housing characteristics
  - Home-apartment type (i.e., mobile home or trailer, one family house detached, one family house attached to one or more houses, apartment or "other")
  - # of apartment units in building
  - year of construction
  - ownership status (rental vs owner-occupied)

Data Considered (5)

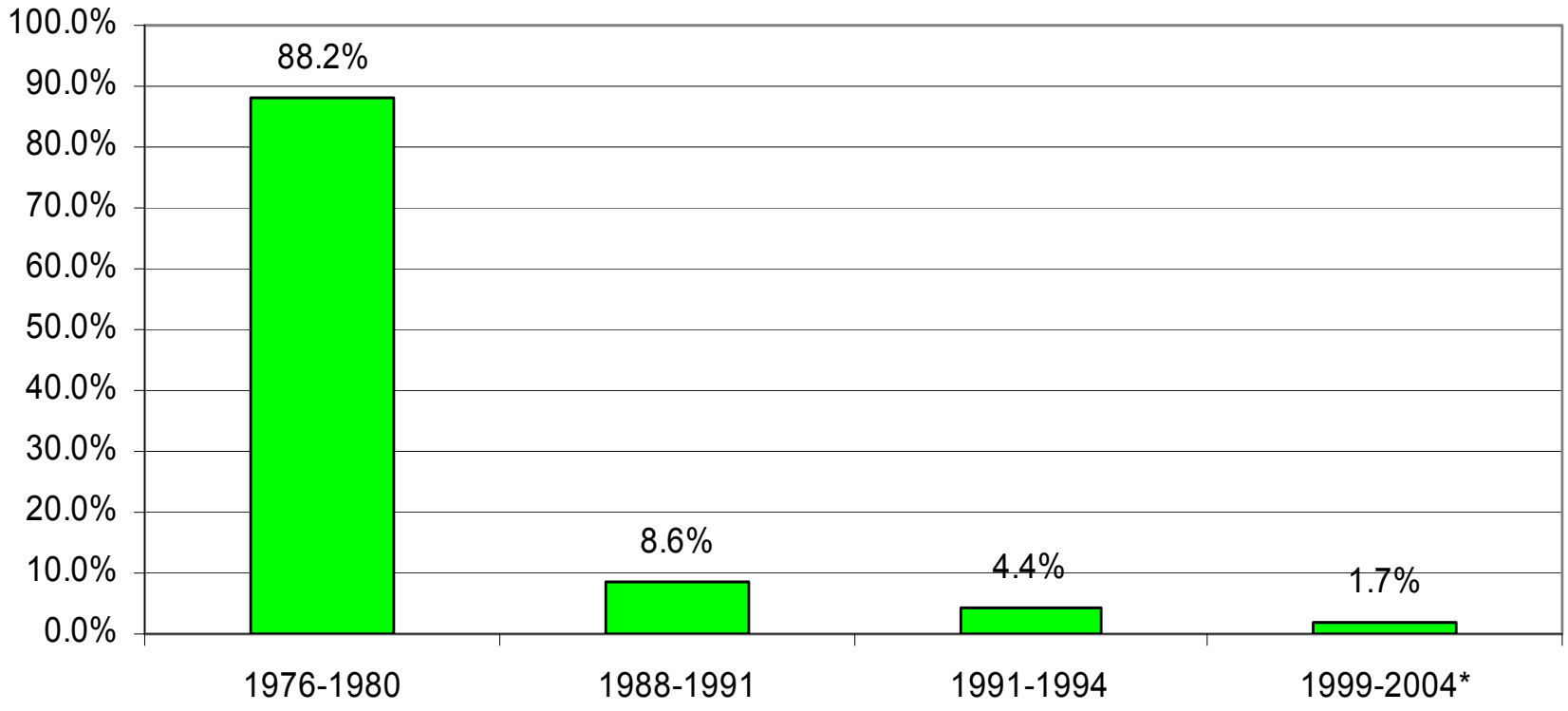
- Possible lead paint hazards in the home (questionnaire)
  - Peeling, chipping, or flaking paint- inside and outside the home
  - Repaint in the past 12 months
  - Scrape old paint in the past 12 months
  - Renovations in the past 12 months

Fig 1: Geometric Mean Blood Lead (µg/dL) for Children 1-5 (NHANES 1976-2004)



* Must have dust testing in the home

Fig 2: Percent Blood Lead ≥ 10 µg/dL for Children 1-5 (NHANES 1976-2004)



* Must have dust testing in the home

Table 1: Geometric Mean Dust Lead and Blood Lead (µg/ft^2)

	All homes	Post-1977 Homes (43%)	Pre-1978 Homes (57%)
Floor dust (µg/ft^2)	0.52	0.30	0.64
Window sill dust (µg/ft^2)	7.64	4.17	10.50
Blood lead (µg/dL)	2.03	1.61	2.17

Table 2: Floor Dust Lead (µg/ft^2)

Floor Dust	% of Post-1977 Homes	% Pre-1978 Homes
<0.5	75.3%	44.7%
0.5-<1	16.7%	24.8%
1-<5	7.6%	25.6%
5-<10	0.4%	2.0%
10-<40	0%	2.6%
40-<130	0%	0.4%

Table 3:
Window Sill Dust Lead (µg/ft^2)

Sill Dust	% of Post-1977 Homes	% of Pre-1978 Homes
<5	66.7%	43.8%
5-<50	29.3%	36.5%
50-<100	0.4%	6.8%
100-<250	2.8%	6.8%
250-<500	0%	4.3%
500-<1000	0.1%	1.2%
1000-<8000	0.7%	0.7%

Statistically Significant Predictors of Blood Lead ($p<0.10$)

- Age (quartic function)
- Race/ethnicity
- Country of birth
- Poverty income ratio
- Anyone smoke inside the home
- Serum cotinine concentration

Statistically Significant Predictors of Blood lead (p<0.10) Cont'

- Year of construction
- Home-apartment type
- Renovation in pre-1978 home
- Deteriorated paint inside pre-1950 home
- Floor surface/condition and floor dust lead (cubic function)
- Sill dust lead

Influence of floor dust lead on blood lead

- Predict blood lead for a range of floor dust lead loadings
  - Pre-1978 homes
  - Sill dust lead corresponding to specific floor dust lead (based on simple linear model for pre-1978 homes)
  - All other variables in model (except sill dust lead) at the population mean for pre-1978 homes

Fig 3: Predicted GM Blood Lead and 90% CI by Floor Dust Lead Loading (NHANES 1999-2004, Pre-1978 Homes)

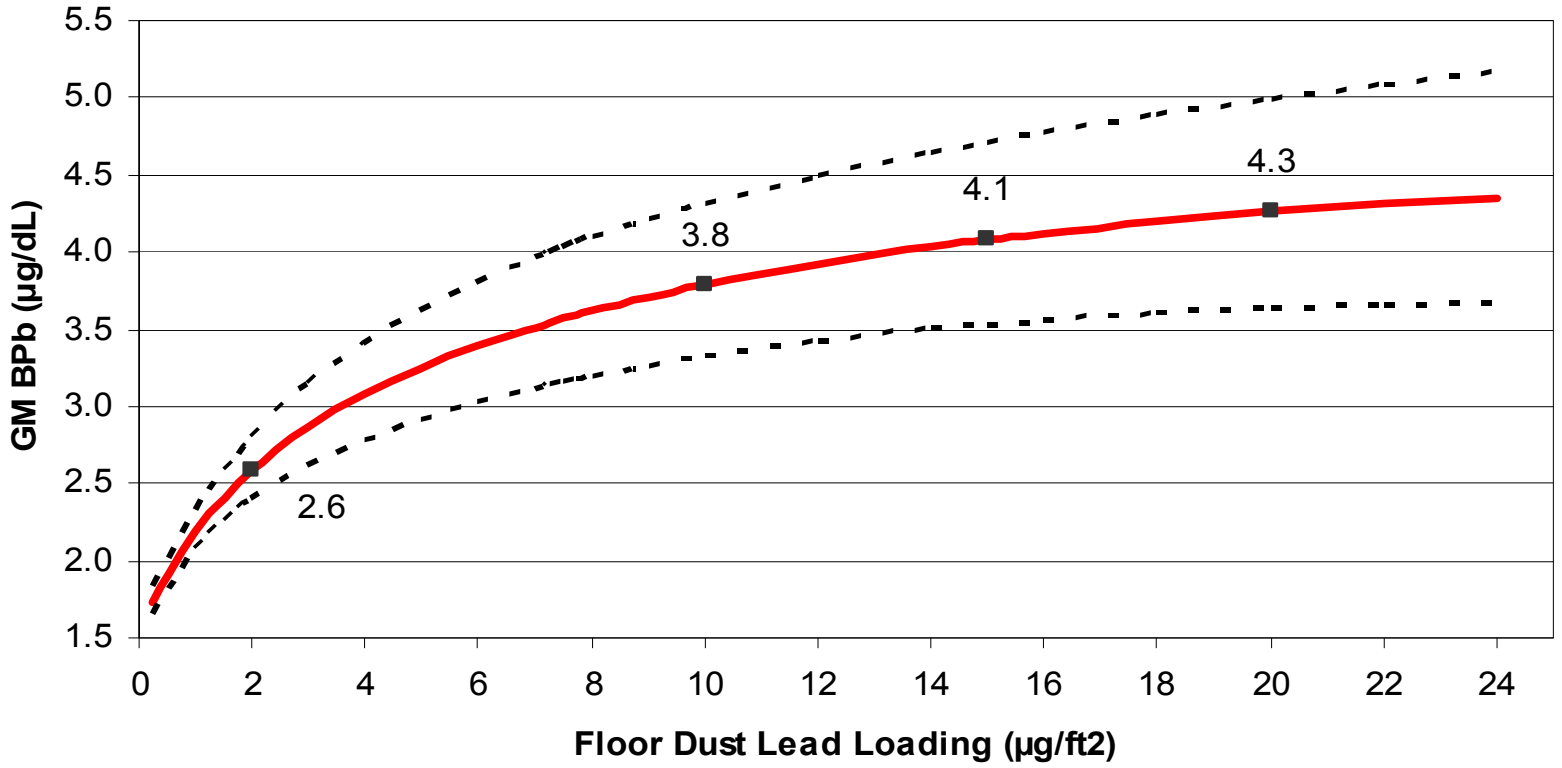


Fig 4: Predicted Probability Blood Lead ≥10µg/dL and 90% CI by Floor Dust Lead Loading (NHANES 1999-2004, Pre-1978 Homes)

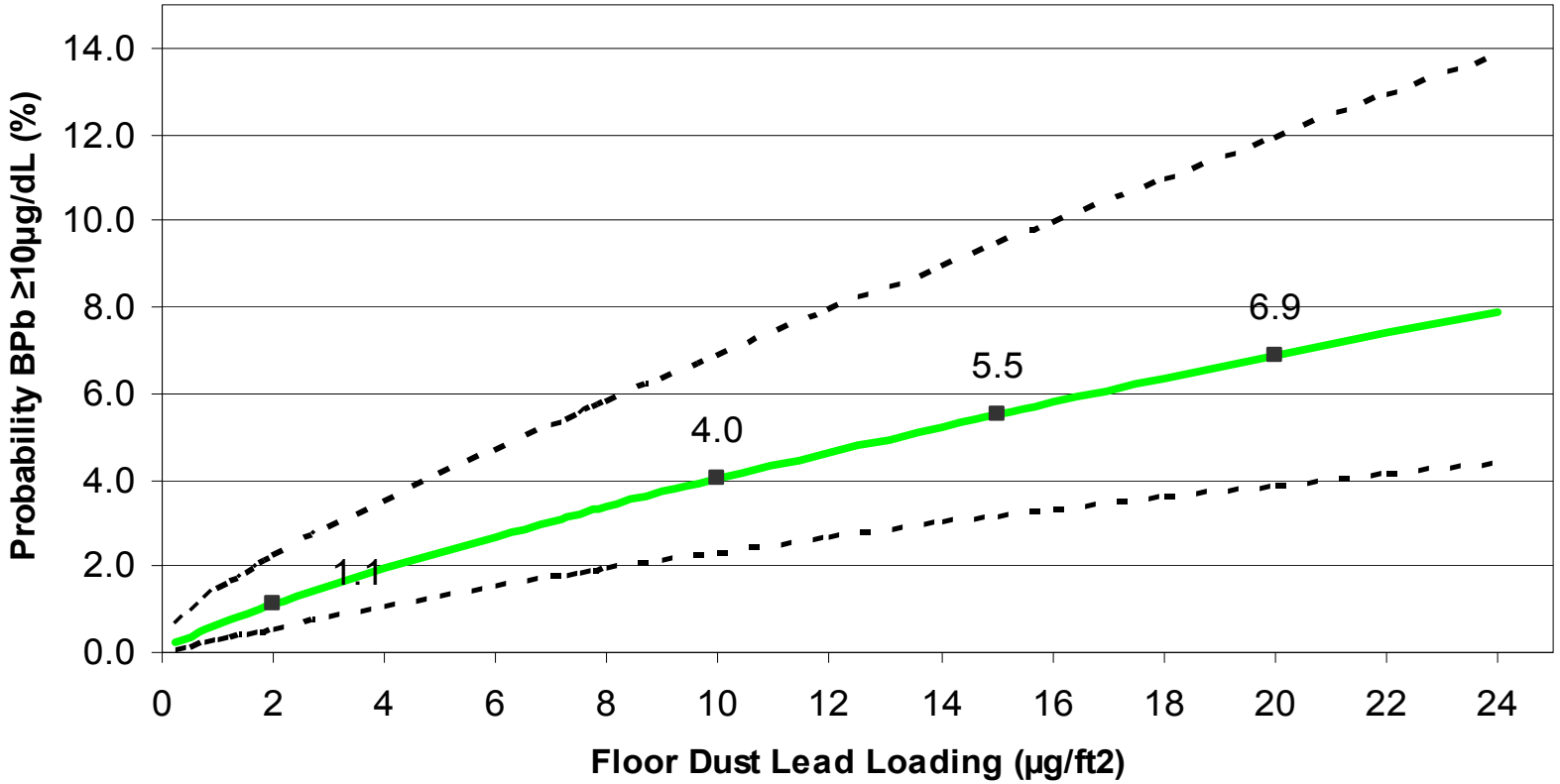


Fig 5: Predicted Probability Blood Lead ≥5µg/dL and 90% CI by Floor Dust Lead Loading (NHANES 1999-2004, Pre-1978 Homes)

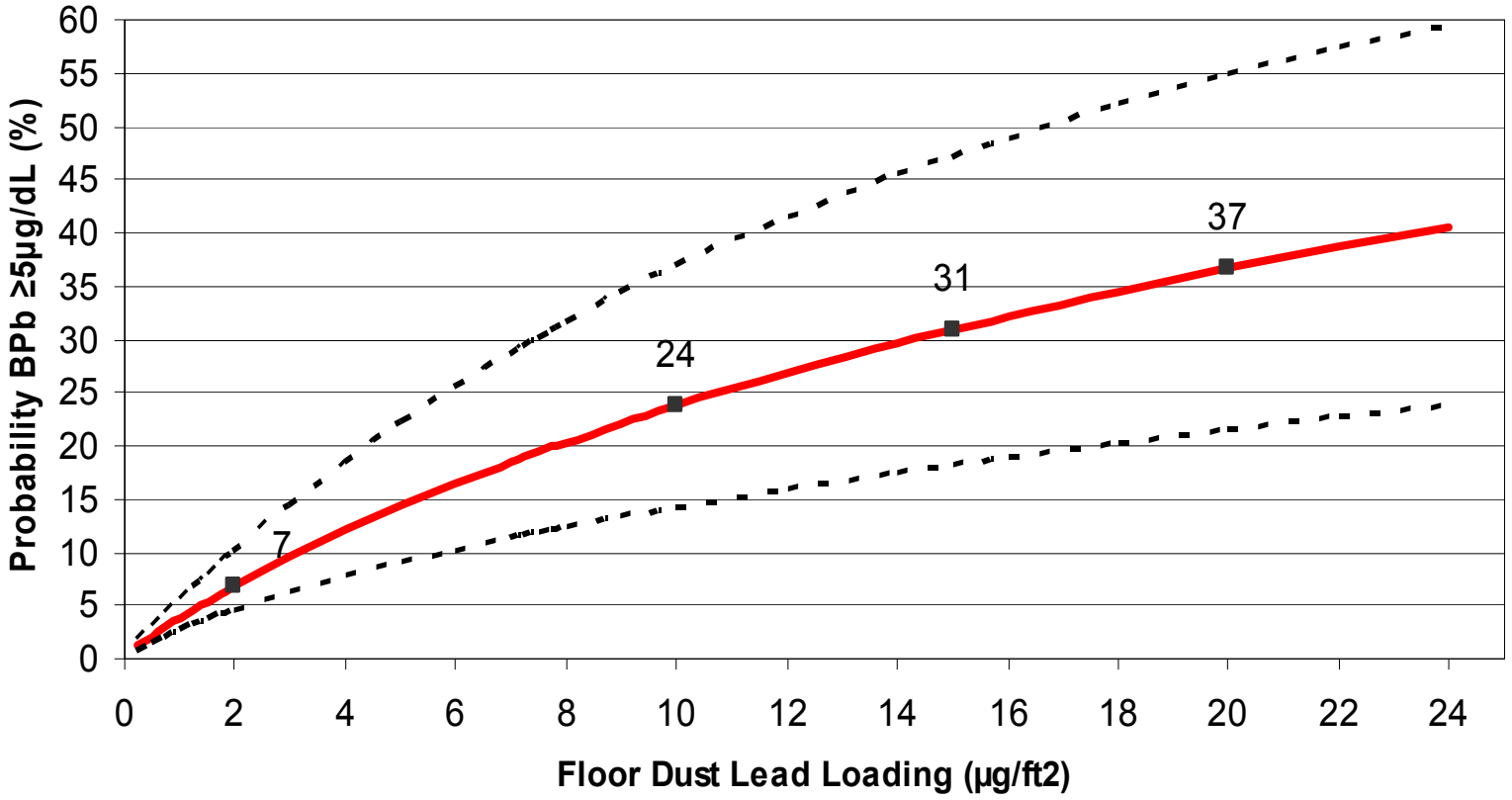


Fig 6: Predicted Blood Lead and Floor Dust Lead (NHANES 1999-2004, Pre-1978 Homes)

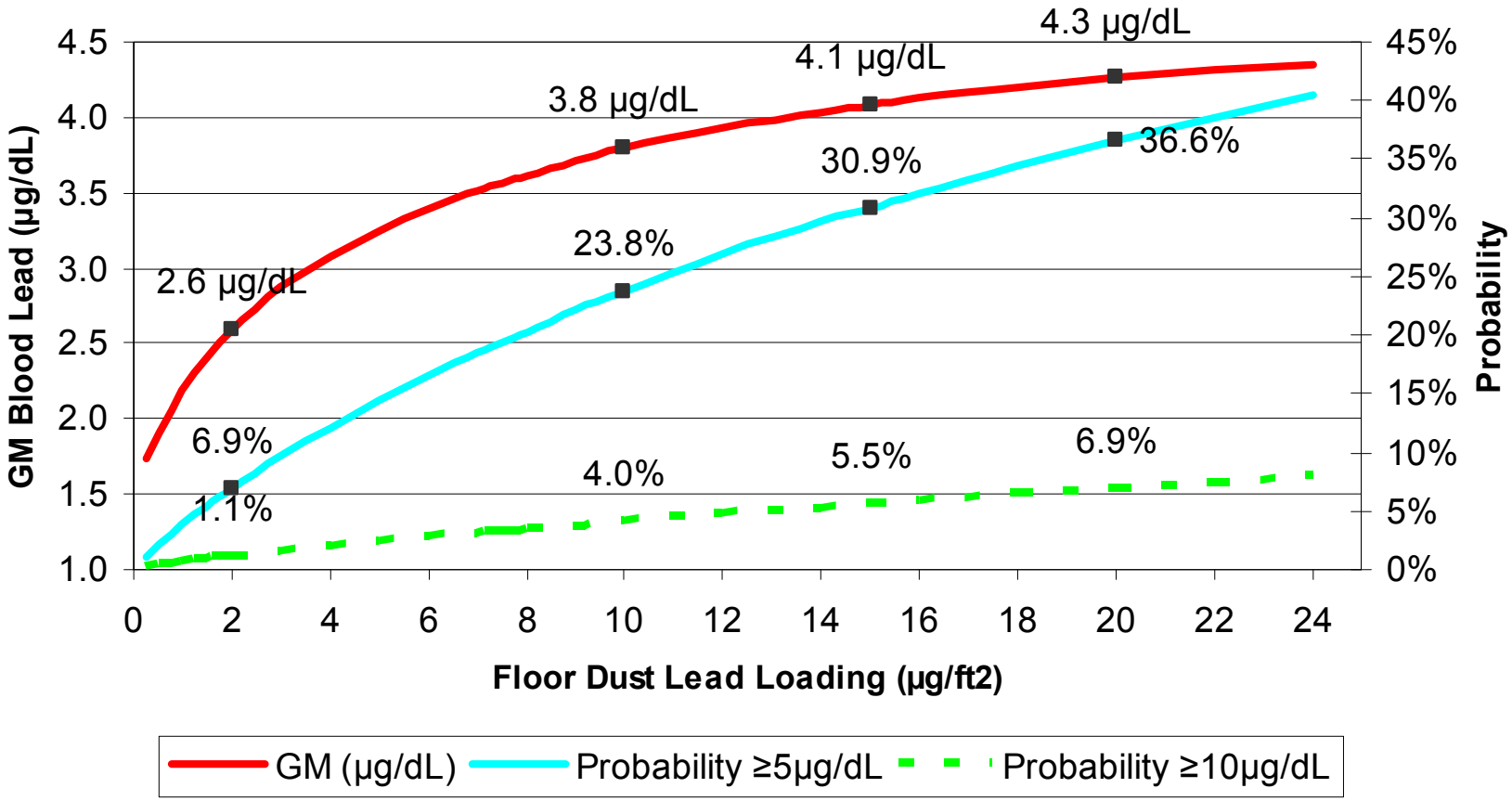
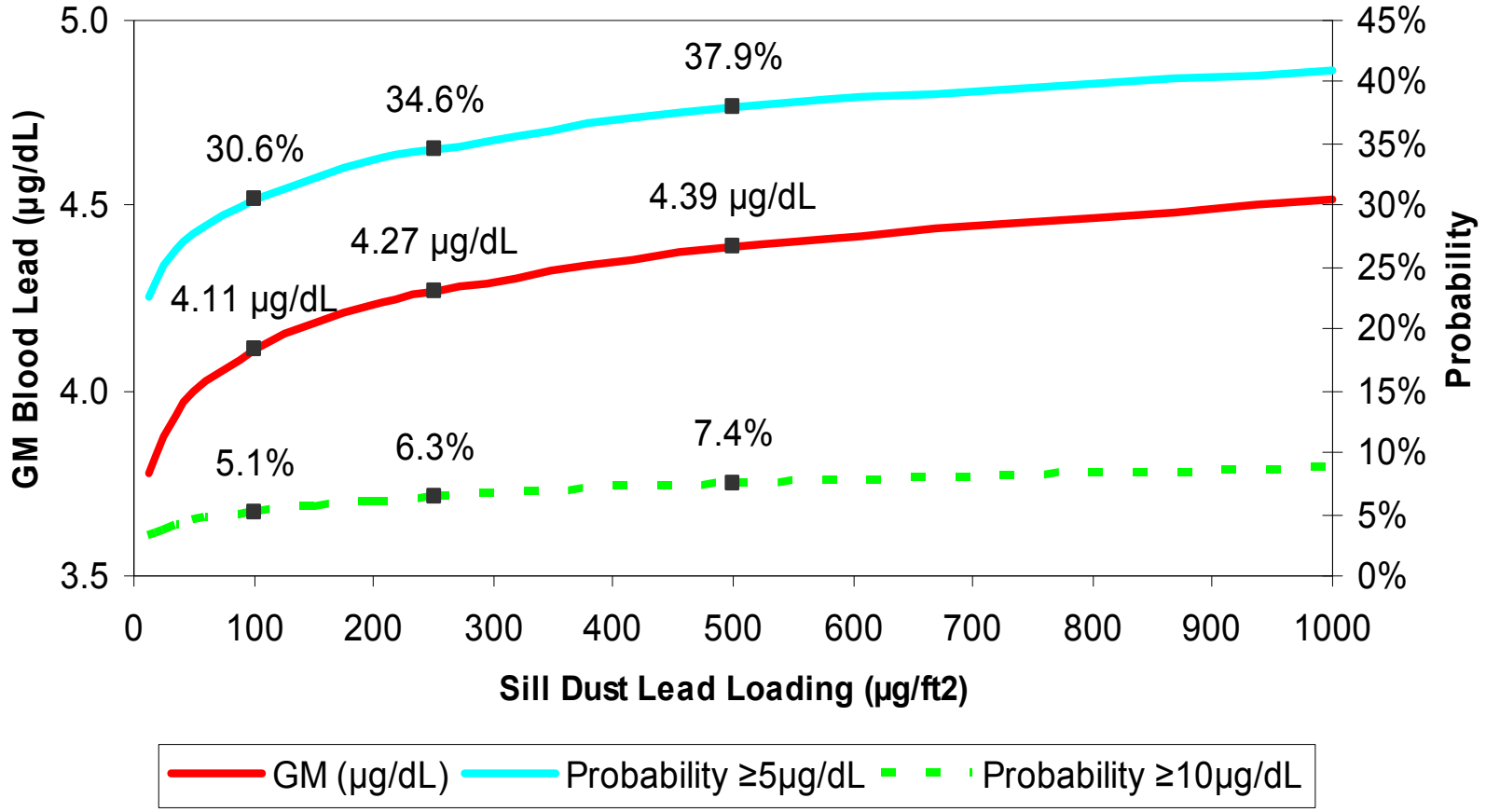


Fig 7: Predicted Blood Lead and Sill Dust Lead (NHANES 1999-2004, Pre-1978 Homes, Floor Dust=12µg/ft2)



Thank You