

What is the impact of environmental non-residential exposure on children's blood lead levels?

**National Training Conference on the Toxics
Release Inventory and Environmental Conditions
in Communities**

Evelyn O. Talbott, Dr.P.H., M.P.H.

Lu Ann Brink, Ph.D.

Environmental Epidemiology

May 7, 2014

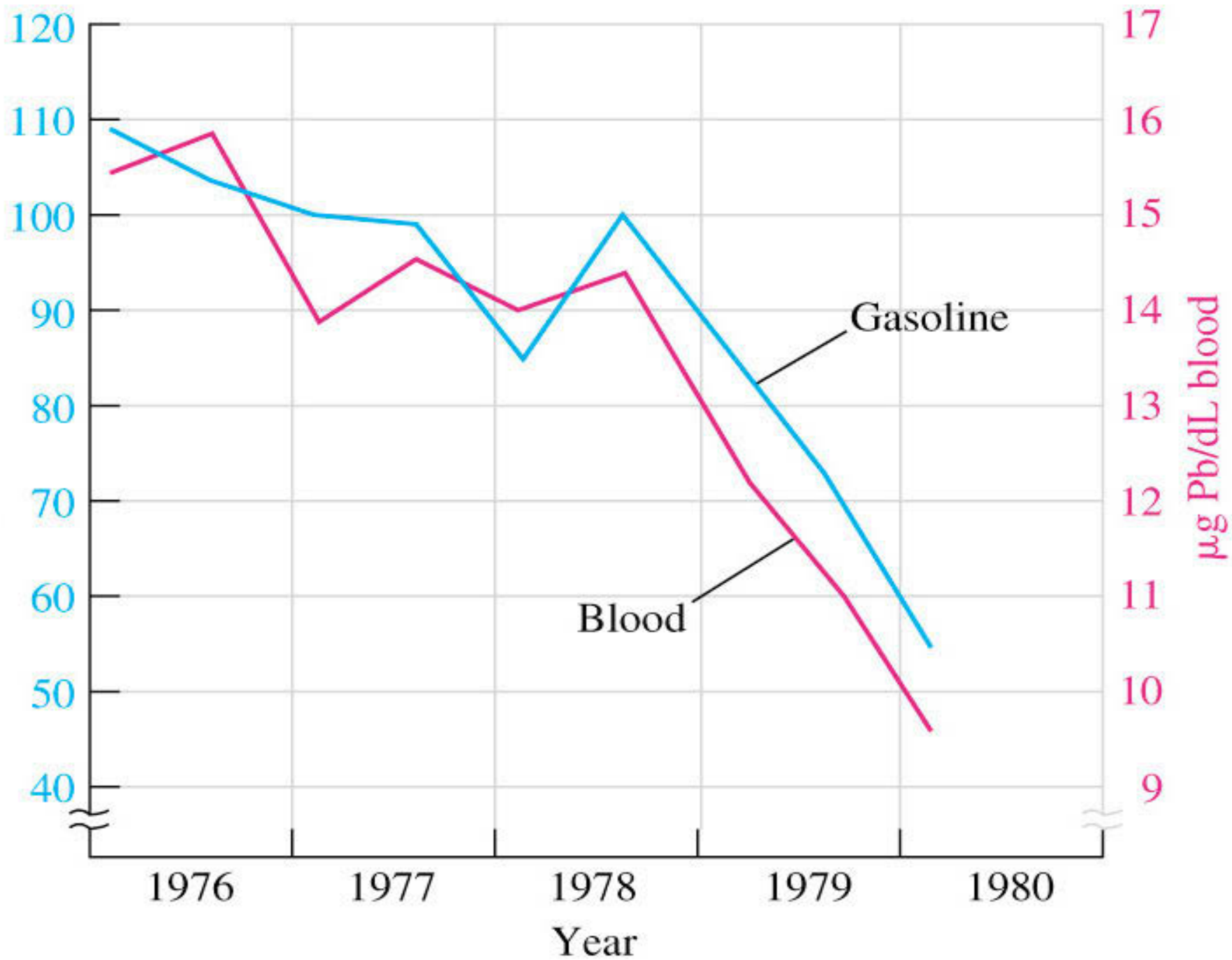
Background

- The health effects associated with PbB at > 10 ug/dl have been well documented.
- These include learning and behavioral problems and the evidence implies that there is no safe level of lead exposure.
- Lead exposure occurs through a variety of sources, air, bare soil, home remedies, drinking water, toy jewelry, and others.
- However the major exposure has been generally thought to have been from deteriorated lead based paint that is ingested during hand to mouth behavior.
- Question is whether there are significant ambient air lead sources from industry and toxic waste sites that also create a significant source of lead exposure.

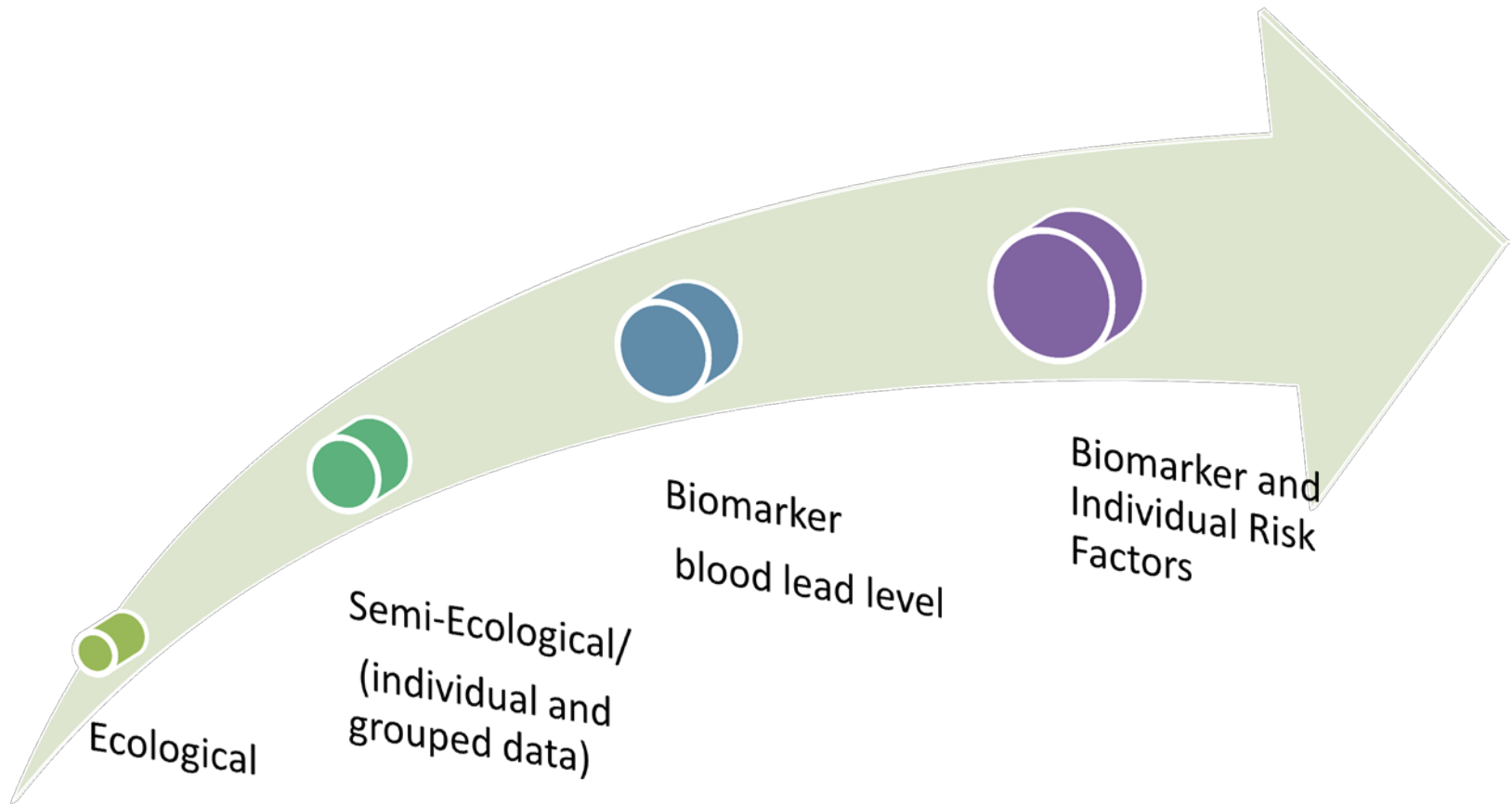
Three Studies will be reviewed

- Contribution of ambient air lead (outdoor) and pre 1950 housing exposures to childhood blood lead levels (ecologic)
- Contribution of ambient air lead (outdoor) from TRI sites linking semi-ecologic or multilevel modeling approaches to individual blood lead data by residence (x,y)
- NHANES study of indoor dust lead levels and childhood blood lead (cross sectional) using individual risk factors within the family for childhood lead levels and the residence in addition to modeled ambient air lead.

Total lead in gasoline, thousands of tons



Evolution of Environmental Epidemiology Studies



Methods for the Ecological Study

- To conduct a comprehensive nation-wide evaluation of the impact of air lead on children's BLLs, the University of Pittsburgh requested childhood blood lead data provided from the CDC for 1644 (52%) of the 3220 US counties for 2000-2007.
- This includes all counties in the following states:

States Providing Aggregate Blood Lead Data by County

Arizona

Louisiana

Ohio

Colorado

Maryland

Oklahoma

Connecticut

Maine

Pennsylvania

Florida

Massachusetts

Rhode Island

Georgia

Michigan

Utah

Illinois

Mississippi

Virginia

Iowa

Missouri

Washington

Kansas

New Hampshire

Wisconsin

Kentucky

New Jersey

Inclusion Criteria

- Any county that had tested a minimum of 50 children (total) between 2000-2007 was included in all analyses.
 - Mean total tested = 3,347
 - Mean population = 92,366
- The excluded counties tested an average of 4 children per year and had an average population of 29,372.

Study: Exposure

- Ecological relationship between county-wide environmental lead sources, pre-1950 housing, and elevated childhood blood lead levels
- Data Sources:
 - National-Scale Air Toxics Assessments (NATA) *modeled* ambient concentrations for 2002 of lead compounds at the county level and were downloaded from the EPA website
 - number of children ≥ 10 ug/dl/number of children tested by county by year were provided through the CDC
 - Percent Elevated (number of children ≥ 10 ug/dl/number of children tested) by year by county were calculated at Pitt
 - Total Elevated (total number elevated in the county/total number tested in the county) was also calculated at Pitt

Non-Residential Sources of Environmental Lead

- Air
 - Major Emissions include: smelting operations and coal burning (power plants, coking)
 - Estimated by NATA, TRI, HBM ,PM_{2.5} estimates
- Soil
 - Legacy waste (fly ash, contaminated manufacturing operations)
 - Estimated by TRI, Superfund inventories



NATA Data

(created in 1996, again in 1999, 2002, 2005 by EPA)

- NATA modeled assessments generally include a four step process including:
 - Compile a national emissions inventory from outdoor sources. The assessment is a state of the science tool which provides estimates of the concentrations and broad estimates of risk from breathing air toxics.
 - Based on sophisticated air dispersion models. EPA estimates ambient concentrations of air toxics for broad categories at the census tract, county and state level.
 - Estimate ambient concentrations of air toxics across the United States, including lead.
 - Estimate population exposures across the United States.
 - Characterize potential public health risks due to inhalation of air toxics. (total of 187 pollutants)

NATA Data for Lead Includes:

- Major Sources
- Area Sources
- Onroad Sources
- Nonroad Sources
- Background Sources

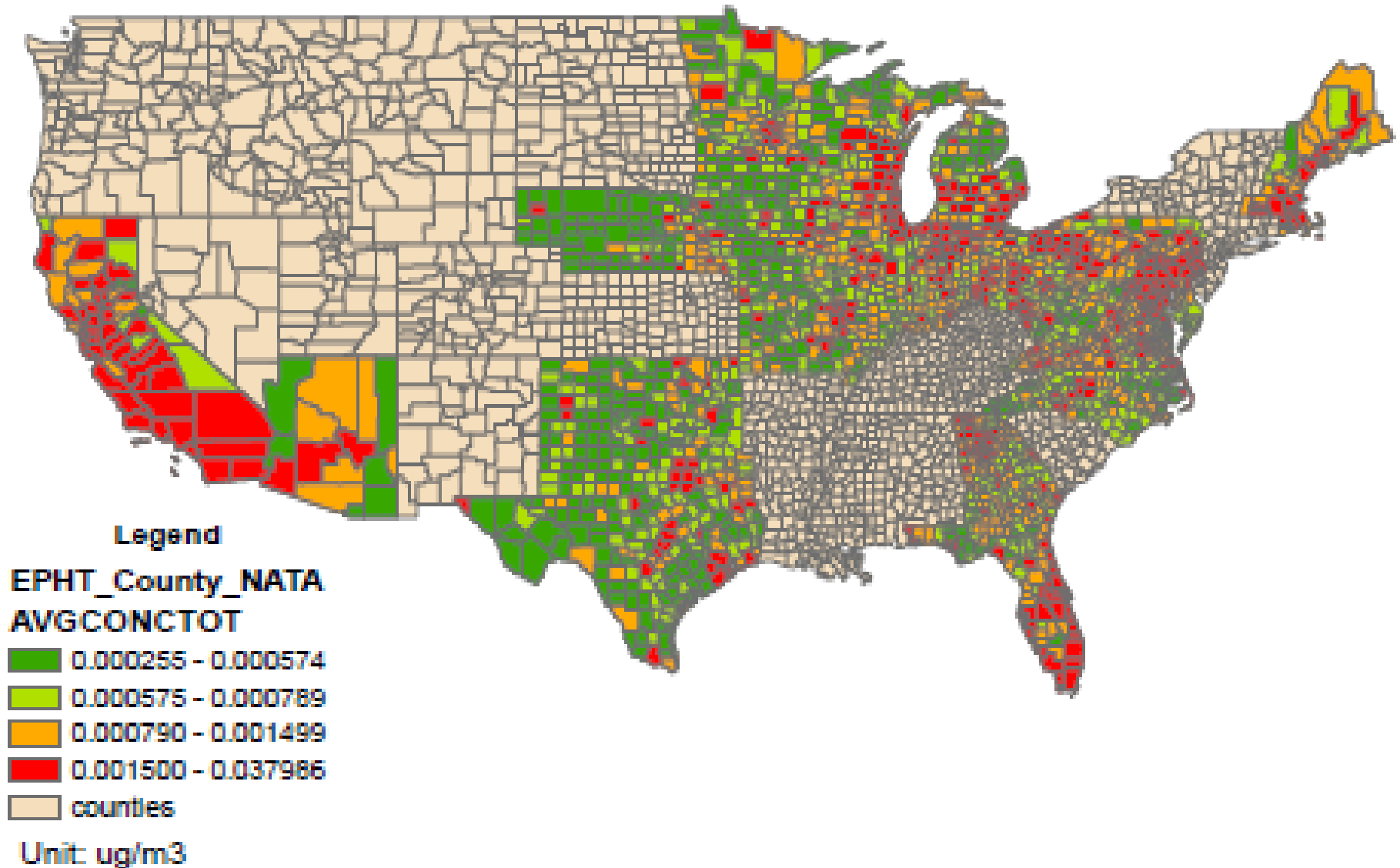
NATA Definitions

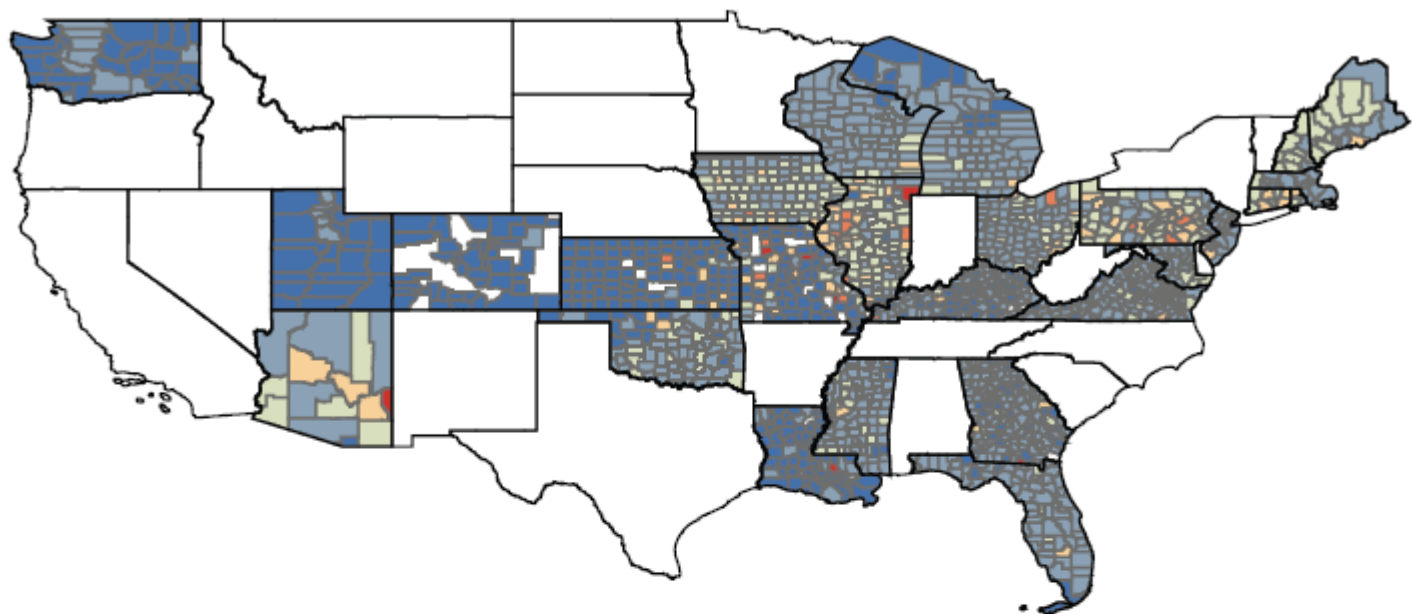
- "Major" sources are defined as sources that emit 10 tons per year of any of the listed toxic air pollutants, or 25 tons per year of a mixture of air toxics. These sources may release air toxics from equipment leaks, when materials are transferred from one location to another, or during discharge through emission stacks or vents

Summary Statistics for 1508 Counties in our Study

- Total children tested aged 0-36 months in 2000-2007 = 5,047,619
- Average NATA air lead concentration in 2002 = 0.00146 ug/m³
- Average NATA air lead concentration in 2005 = 0.00127 ug/m³
- Mean percent elevated per county=1.01%

The Distribution of Ambient Concentration from Total Sources 2002 Lead Compounds by Quartile by County





Total percent elevated of lead

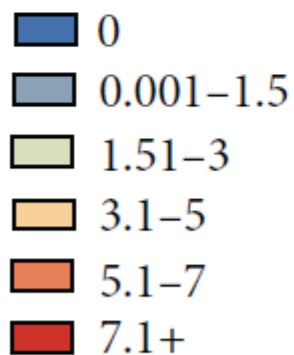


FIGURE 2: Cumulative percentage of children with $BLL \geq 10 \mu\text{g/dL}$ by county, 2000–2007.

Descriptive Statistics for 1508 Counties

	Percent Below Poverty n=1508	Percent Rural	Percent Black	Percent Pre-50	Population
Mean	13.6	56.8	10.6	25.7	97366
Min	2.6	0	0.26	0.78	1844
Max	41.13	100	86.5	66.7	5376741

Results of Multiple Linear Regression Proportion of Children ≤ 3 years of age with > 10 Pb ug/dl by County

	Standardized Beta	Significance
%Pre-1950 housing	0.165	<.001
NATA Total sources of Pb ug/m ³	0.339	<.001

Limitations:

- Variability of county level average for NATA may be vastly different: eg. NATA lead estimates for urban census tracts within Allegheny County (Pittsburgh), PA range from 0.0694 to 0.00297 $\mu\text{g}/\text{m}^3$ (23-fold difference, n=416 CTs)
- NATA lead estimates for rural census tracts within neighboring Armstrong County, PA range from 0.00189 to 0.000629 $\mu\text{g}/\text{m}^3$ (3-fold difference, n=18 CTs)

II. Second Approach: semi ecologic (Multi-level) study: Kansas

The second approach involves a combination:

1. individual level data on childhood blood lead levels, age, gender and residence. Approx. 50,000
2. x,y longitude and latitude of residential location of each case.
3. ecologic: census tract or zip code census information on % pre 50 housing, % poverty.
4. ecologic: proximity from Toxic release source and census tract level of modeled air lead level.

Kansas Conceptual Framework

Local Environment
Physical Environment:
lead exposure;
modeled ambient lead
by distance from TRI
site or CT level Lead
(NATA)

Social Environment:
Poverty level, housing
quality, racial
composition(census
data) pre 50/poverty



Micro Level:
Child's race, age,
Individual blood
lead level, x,y

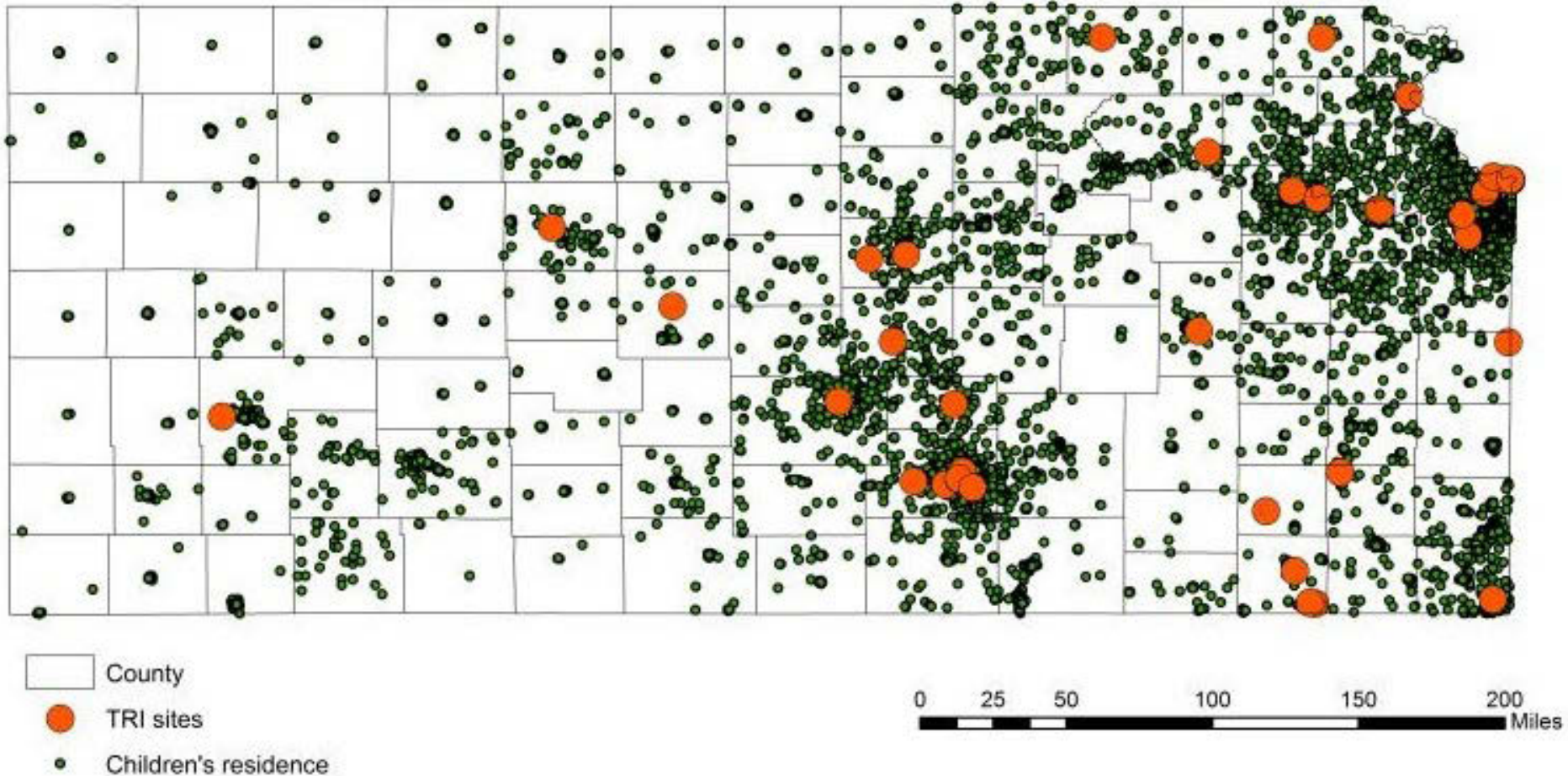


Elevated
Blood Lead
Level

Methods

- Select TRI sites with total release of lead/lead compound greater than 500 pounds
- Measure the distance from each TRI site to individual's x, y coordinates of residence by using map projection in ArcGIS

Kansas Individual Childhood Blood Lead and TRI Sites



Comparison of Analyses

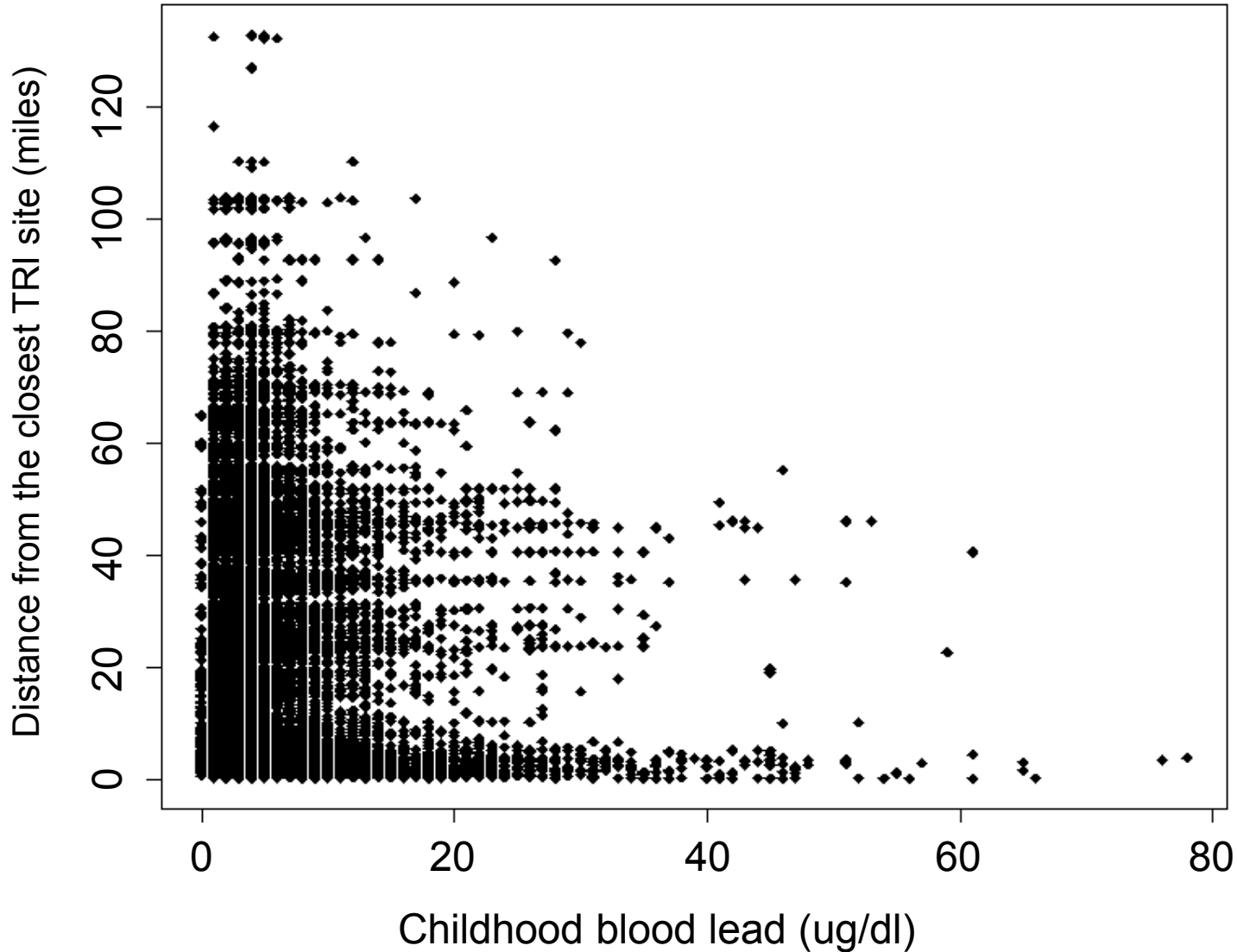
Ecological

- Estimates of modeled air lead levels by county and the number of children with elevated blood lead (% >10 ug/dl) by county

Individual

- Those who live closest to a TRI site have a mean BLL of 2.27, ug/dl (< 3 miles)
- Those who live at the greatest distance from a TRI lead-emitting site have a mean BLL of 1.82
- $P < .001$

Distance from TRI Site by Individual Childhood BLL ($\mu\text{g}/\text{dl}$), KS 2000-2007



Summary Table of Distance from the Closest LEAD TRI Site and Childhood Blood Lead Data

Table 1: Descriptive characteristics of population by distance from lead TRI site.

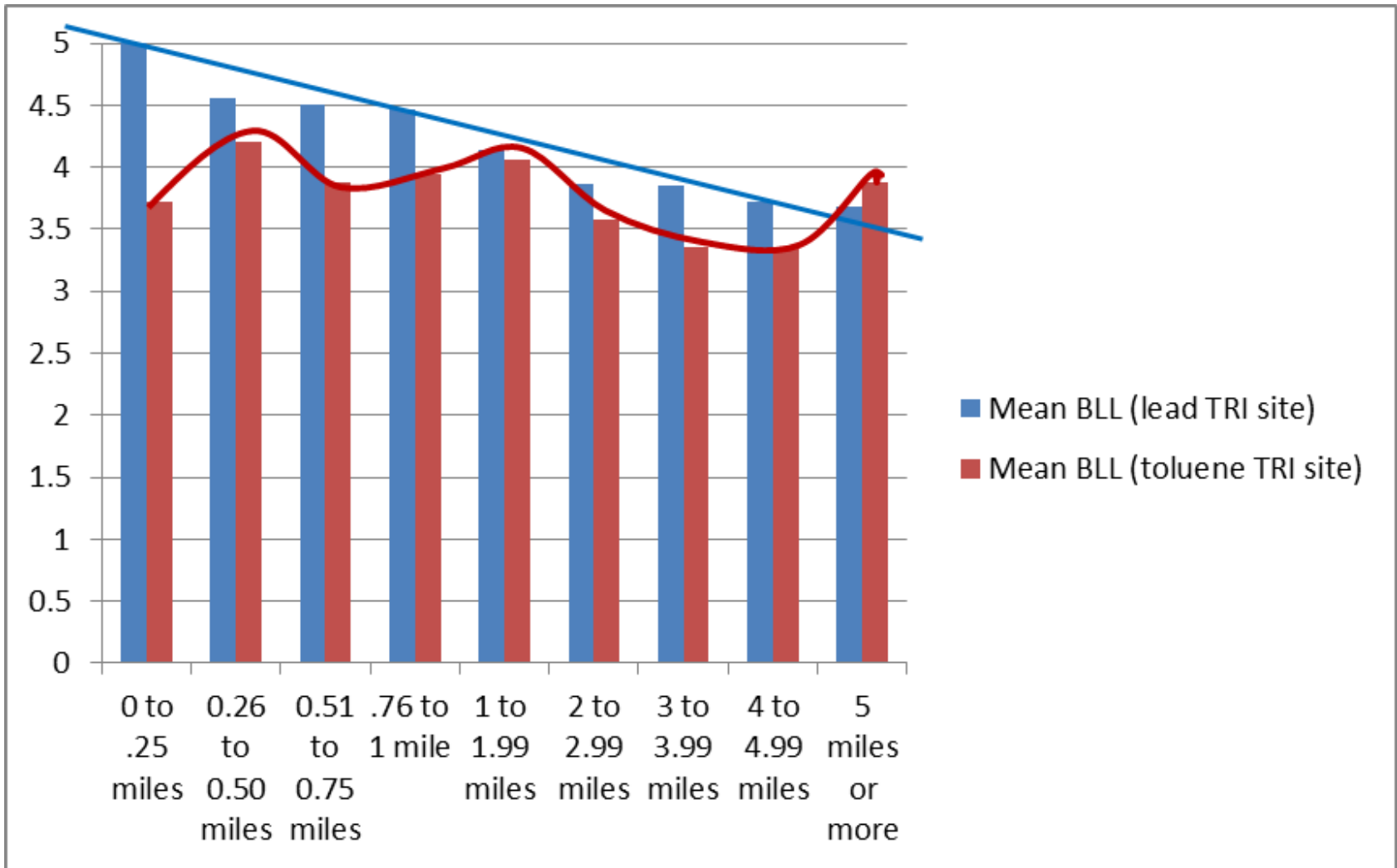
Distance from TRI site (miles) with >500 pounds of lead	Number of children	Mean BLL	Mean % pre-50 housing	NATA 2005 air lead estimates (*10 ⁻³)	Mean % poverty	Percent with blood lead >= 10 ug/dl	Percent with blood lead >= 5 and <10 ug/dl
0 to .25	99	5.01	65.00	1.28	18.34	11.11	18.18
0.26 to 0.5	355	4.56	67.80	1.50	18.58	7.89	23.94
0.51 to 0.75	590	4.50	70.05	2.00	19.51	5.93	27.29
0.76 to 1	1028	4.47	70.86	2.52	21.86	6.32	27.82
1 to 1.99	4398	4.14	63.52	3.64	16.77	4.18	24.53
2 to 2.99	4649	3.87	56.53	2.59	15.33	3.48	20.82
3 to 3.99	4598	3.85	53.45	1.93	16.15	3.45	20.81
4 to 4.99	2762	3.72	44.93	1.61	14.11	2.82	20.20
5 or more	22749	3.68	40.26	0.91	9.84	2.88	20.51

Summary Table of Distance from the Closest TOLUENE TRI Site and Childhood Blood Lead Data

Table 2: Descriptive characteristics of population by distance from toluene emitting TRI site.

Distance from TRI site (miles) with >500 pounds of lead	Number of children	Mean BLL	Mean % pre-50 housing	NATA 2005 air lead estimates (*10 ³)	Mean % poverty	Percent with blood lead >= 10 ug/dl	Percent with blood lead >= 5 and <10 ug/dl
0 to .25	88	3.72	52.82	.340	33.52	3.41	26.14
0.26 to 0.5	331	4.21	54.88	.146	28.71	5.44	29.31
0.51 to 0.75	468	3.88	53.86	.086	23.36	3.42	26.28
.76 to 1	1005	3.95	55.80	.075	24.72	3.68	25.37
1 to 1.99	6587	4.06	59.13	.030	25.18	4.16	27.86
2 to 2.99	4926	3.58	49.38	.026	19.44	2.56	22.21
3 to 3.99	2631	3.36	41.44	.032	17.65	1.90	20.37
4 to 4.99	2035	3.34	30.59	.015	12.65	1.97	18.23
5 or more	23157	3.88	46.03	.012	14.65	3.52	25.14

Comparison of BLLs based upon proximity to type of TRI site



Preliminary Multilevel Modeling

Variable	Coefficient (β)	Standard Error	Z	P-value	CI
Miles from TRI site	-0.0099775	0.0037025	-2.69	0.007	-0.0172342 to -0.0027208
Age	0.0103863	0.000457	22.73	<0.001	0.0094906 to 0.0112819
% poverty	0.0058258	0.0011312	5.15	<0.001	0.0036087 to 0.0080428
% pre-50	0.0027187	0.0003526	7.71	<0.001	0.0020277 to 0.0034098
constant	0.7681637	0.0291125	26.39	<0.001	0.7111042 to 0.8252231

Background on Database: Exposure of US Children to
Residential Dust Lead 1999-2004: NHANES
(Dixon, et al, EHP, 2009)

- Cross-sectional study that collected health, housing, and environmental data in a single integrated national survey at *one point in time*.
 - 2,155 children 12-60 months with lead *blood* and lead *dust* measurements
 - Analyzed in case-control (high blood lead and low blood lead; logistic regression) and continuous fashion (linear regression)

Risk Factors of Elevated Blood Lead Level (BLL)

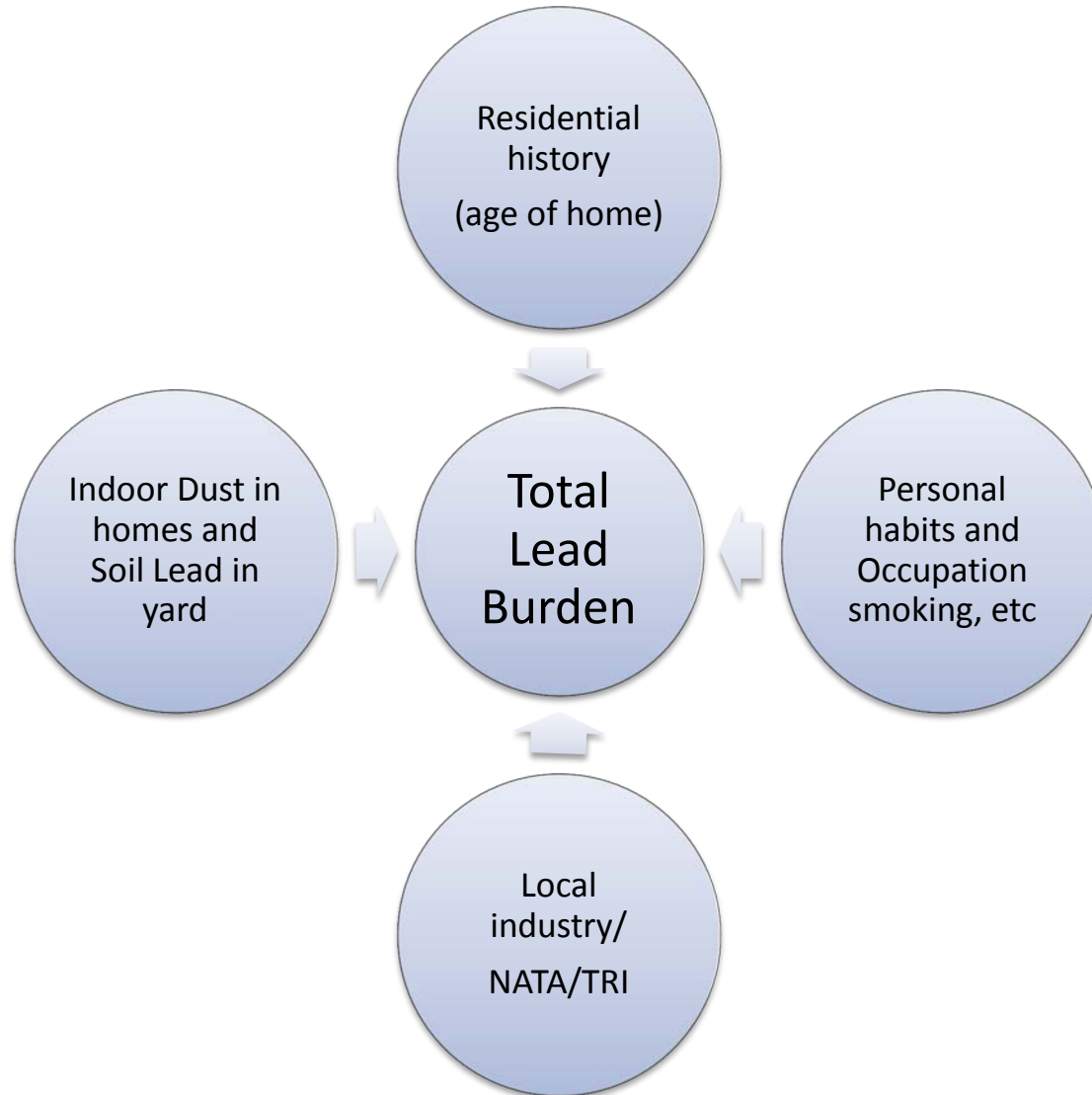
- Floor lead dust concentration
- Window ledge lead dust concentration
- Foreign born
- Rough, uncleanable floors
- Older home (pre-1978, pre-1950)
- Minority (black, Hispanic)
- Renovation within a year
- Single family home
- Smoking in home
- Cotinine concentration (after controlling for smoking)

Lead Dust as a Risk Factor

For homes built before 1978

- Floor PbD of **6** ug/ft², **2.7%** of children have PbB \geq 10 and **16.5%** have PbB \geq 5 ug/dl, and geometric mean PbB = **3.4** ug/dl
- Floor PbD of 12 ug/ft², **4.6%** of children have PbB \geq 10 and **26.8%** have PbB \geq 5, and geometric mean PbB = **3.9** ug/dl

III. Use of NHANES Data to obtain a fuller story (total burden) use of individual level data on household and micro environment: biomarker level and individual risk factors



NHANES Variables of Interest

- We utilized NHANES data (1999-2006) to look at the association between blood lead levels in children and air lead concentrations from NATA data and proximity to TRI sites adjusting for confounders
- Variables from NHANES included cotinine levels, childhood blood lead levels, and indoor floor dust samples
- Census tract variable percent-pre50 housing was used
- Survey Weighted analyses were used to assess the distribution of blood lead levels nationally
- Multilevel un-weighted Regression analysis was used to evaluate influence of NATA and TRI on blood lead levels

Descriptive Statistics

- A total of 3,223 children were included
- Overall GM BLL was 1.73 ug/dL (95%CI: 1.65-1.82)
- Non-Hispanic Black children had highest GM BLL 2.58 ug/dL
 - Non-hispanic white children: 1.59 ug/dL
 - Hispanic children: 1.69 ug/dL
- BLL were highest in the NE (2.21 ug/dL) and lowest in the West (1.34 ug/dL)

Descriptive Statistics Continued

- Sample size reduced to 2253 with inclusion of cotinine and lead dust variables
- Overall GM BLL was 1.70 ug/dL (95%CI: 1.59-1.82)
- Non-Hispanic Black children had highest GM BLL 2.52 ug/dL
 - Non-hispanic white children: 1.56 ug/dL
 - Hispanic children: 1.66 ug/dL
- BLL were highest in the Midwest (2.06 ug/dL) and lowest in the West (1.35 ug/dL)

Regression Analyses

- After adjusting for sex, race, age in months, reference adult's education, %pre-50 housing, PIR, region and survey cycle) for every 10,000 lbs/mi² increase in cumulative TRI exposure there was a 1.13% (95%CI: 0.45, 1.81) increase in GM BLL
- With additional adjustment for lead dust and cotinine, TRI was no longer significant
- NATA was significant in the univariate model, but after adjustment it was no longer significant

Stratified Analyses

- After adjustment for the full model with lead dust and cotinine
 - NATA: for each 1 ng/m³ increase in ambient air lead there was a 2.16% increase in GM BLL for children screened from 1999-2000
 - TRI: for each 10,000 lb/mi² increase in cumulative exposure there was a 5.39% increase in GM BLL for children screened from 2003-2004
 - For each 10,000 lb/mi² increase in cumulative exposure there was a 1.92% increase in GM BLL for females

Three Analyses – similar conclusions

- Used two types of environmental measurements – TRI and NATA
 - TRI is used to estimate NATA, although NATA more clearly estimates exposure
- Both convey a small but significant risk of either *elevated BLL* or *increased BLL*
- **After adjustment for age of home and poverty, environmental lead appears to increase childhood BLL**