Published in final edited form as:

Environ Sci Technol. 2019 May 21; 53(10): 6000–6006. doi:10.1021/acs.est.9b00429.

Lead and Arsenic in Shed Deciduous Teeth of Children Living Near a Lead-Acid Battery Smelter

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Abstract

Lead (Pb) is a potent neurotoxicant with no safe level of exposure. Elevated levels of Pb and arsenic (As) are found in the air and soil near facilities that recycle lead-acid batteries in the United States. In urban Los Angeles County, California, a facility processed ~11 million batteries per year and operated for decades without proper environmental review. Measuring Pb and As in shed deciduous teeth is a promising technique to assess prenatal and early life exposure. In this pilot study coined the “Truth Fairy” Project, 50 shed deciduous teeth from 43 children living their entire lives within 2 miles of the smelter were analyzed to understand retrospective exposure to toxic metals using a community-driven research approach. Concentrations of Pb and As in teeth were assessed using laser-ablation-inductively coupled plasma-mass spectrometry. Soil Pb concentrations were determined using spatial kriging of surface soil measurements. The mean prenatal calcium normalized Pb levels in teeth samples (reported as a ratio $^{208}\text{Pb}:^{43}\text{Ca}$) was 4.104×10^{-4} (SD 4.123×10^{-4}), and the mean postnatal $^{208}\text{Pb}:^{43}\text{Ca}$ level was 4.109×10^{-4} (SD 3.369×10^{-4}). Adjusted for maternal education and batch, we observe positive significant relationship between prenatal teeth Pb per 100 ppm increase in soil Pb ($\beta=3.48$, 95% CI 1.11, 5.86). The Truth Fairy study suggests prenatal and early life exposure to toxic metals is associated with legacy soil contamination in an urban community near a smelter.

Introduction

The tonnage of lead-acid batteries recycled in the United States (US) has more than doubled over the last 40 years, as the industry has consolidated production into a handful of facilities. The US is the second leading producer of refined lead (Pb) after China, accounting for approximately 19% of the world’s recycled lead (or ~1.1 million tons per year).¹ The majority of Pb is derived from processing lead-acid batteries, and because batteries are heavy they are expensive to transport, smelters are typically located near the largest sources of scrap (i.e. large cities).² During the smelting process, batteries are cracked, washed,

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ASSOCIATED CONTENT

Supporting Information includes Figure S1 and Figure S2. The following pdf contains all of supporting information and is available free of charge.

pulverized and melted in a furnace, during which pollutants are released to the environment. The highest levels of Pb in US ambient air are found near lead-smelting facilities.³ Lead concentrations in shallow soil near smelters may reach levels in the parts per thousand range and can persist indefinitely.⁴

Inorganic Pb is one of the most ubiquitous toxic substances and is an extremely potent neurotoxin. At elevated levels, it can cause damage to almost all organs and organ systems.⁵ Cognitive deficits, neurodevelopmental delays and psychological impairments are associated with low levels of Pb exposure.⁶⁷ Lead has been the target of environmental regulations in the US for decades, and extensive scientific evidence demonstrates that there is no “safe” threshold of childhood Pb exposure.⁸⁹ Cases of childhood Pb poisoning have been identified at battery recycling operations in the US with soil Pb contamination identified as the primary exposure pathway.¹⁰ In addition to Pb, a mixture of metals is typically emitted from secondary smelters, and soils near smelters have been found to have elevated concentrations of arsenic (As) and antimony (Sb), and to a lesser extent cadmium (Cd) and manganese (Mn).¹¹¹²¹³

Until 2015, a secondary Pb smelter processed ~11 million batteries per year in urban southeast Los Angeles County, California. The surrounding areas are densely populated neighborhoods of predominantly working-class Latino residents.¹⁴ A 2013 Health Risk Assessment by the South Coast Air Quality Management District, a regulatory agency, concluded that as many as 250,000 residents face a chronic health hazard from exposure to Pb and As emitted from the smelter that subsequently settles in residential soil.¹⁵ In March 2015, the battery smelter permanently ceased all operations as part of a legal settlement for hazardous waste violations.¹⁶

Leveraging a community-academic collaboration, we designed the “Truth Fairy” project aimed to conduct retrospective assessment of prenatal and early life exposure to toxic metals possibly associated with the smelter. While blood-Pb levels are commonly used as an indicator of Pb exposure, levels only reflect recent exposures due to the short half-life of Pb in blood, which is approximately 4 weeks.¹⁷ Blood-Pb levels also decline when exposure declines, but past exposures may be important indicators of harm.¹⁸ Analysis of shed baby teeth provides a non-invasive biomarker to estimate past exposure during critical windows of child development.¹⁹²⁰ In the human fetus, deciduous teeth begin mineralizing near the start of the second trimester and incorporate minerals (including metals) as they grow.²¹²⁰ The formation of enamel and dentine in teeth occurs incrementally with enamel completed around 1 year of age for the latest forming primary tooth. The timing of crown completion as well as the pattern of mineralization vary predictably for both enamel and dentine formation.¹⁹ Prior research has related Pb levels in dentine with maternal pregnancy blood Pb levels and postpartum maternal patella Pb levels,²²²³ and reported a significant association between child blood Pb levels at 3 months and dentine formed at ~3 months of age.²³ The dental biomarker technique has been successfully applied in cohorts in the US to assess pre- and post-natal exposures to toxic metals.²⁴²⁵²⁶ Additionally, parents frequently save their child’s teeth, which offer archives of samples to assess retrospective exposures in this community. In this study we analyzed Pb and As in the prenatal and postnatal dentin of

shed teeth from children who lived <2 mi from the smelter while in utero and during their early childhood period, and assessed the association with soil Pb levels from the community.

Methods

Study Area.

Lead contamination is present in parts of Boyle Heights, East LA, Commerce, Maywood, and Huntington Park (Figure 1). Residents of the study area were recruited if they lived in the exposed area since pregnancy with the child, were willing to donate 1–2 shed teeth per child, and were proficient in English or Spanish. Donated teeth needed to be whole (e.g. not broken) and cavity- and filling- free. Recruitment was conducted through elementary schools, churches, parent workshops and door-to-door blockwalking activities. Community organizations held meetings to inform community members about environmental health, describe the study, and connect potential participants with academic partners. Community partners were further involved in the interpretation and dissemination of the findings.

Demographics and Other Characteristics.

Demographics, health behaviors, pregnancy and birth information, infant feeding practices and residential history of the child were obtained by direct interview of the child's parent or guardian. Participants responded to a detailed list of occupations (e.g. automotive repair, metal smelter, home repair/painting, welding) of anyone living in the home during pregnancy and early life of the child to assess potential take-home work-related Pb exposures. This information was dichotomized to indicate whether anyone living in the home of the child worked in an occupation with potential Pb exposure. Maternal educational attainment was classified as no high school degree, or high school graduate. Housing age was abstracted from the Los Angeles County Property Assessment Information System and dichotomized to identify those built before or after 1978, the former providing an indicator of homes more likely to have Pb-based paint.

Tooth Metal Measurements.

Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) for tooth analysis is a sensitive analytical technique that offers detection limits suitable for the analysis of trace elements in teeth. This approach focuses a 30 µm diameter laser beam onto the surface of the tooth sample from which material is ablated, with the ejected particles then carried to the ICP-MS where they are ionized and separated based on mass-to-charge ratios. The neonatal line (a histological feature formed in enamel and dentine at birth) and daily incremental markings on each tooth are used to assign temporal information to sampling points.²⁷²³ This approach allows temporal stratification into pre- and post-natal periods to examine differences in exposure related to maternal (prenatal) and environmental pathways (postnatal). Laboratory analyses adjust for calcium content (⁴³Ca) to control for any variations in mineral content within a tooth and between samples, providing metal-to-calcium ratios (e.g. ²⁰⁸Pb:⁴³Ca). Samples of teeth that were cracked or had visible signs of excessive attrition that could impact chemical analysis were excluded. In this study, teeth were analyzed in two batches (October 2017 and March 2018), which we adjusted for in the final models. The detection limit was 0.05 µg/g for Pb and 1.0 µg/g for As.

Soil Measurements and Spatial Analysis.

Soil Pb data was extracted from records of the California Department of Toxic Substances Control (DTSC). Nearly 8,000 properties within 1.7 miles of the smelter facility were tested for Pb by the DTSC, and as of March 2018, 117,356 samples from the top 1–3 inches of soil were analyzed and geocoded. As many residential locations were repeatedly sampled, the DTSC calculated a representative soil Pb concentration using the upper 95% confidence level for properties with at least 8 samples or the maximum for those with 7 or fewer samples (<https://www.epa.gov/land-research/proucl-software>).

To estimate soil Pb exposures, empirical semivariograms were constructed using the robust Cressie-Hawkins estimator.²⁸ The theoretical semivariogram function that was the best weighted least squares fit to the empirical data, chosen from exponential, Gaussian, spherical or Matern, was selected based on the reasonableness of the spatial parameter estimates and smallest sum of squares. Sensitivity analyses were conducted by varying the initial spatial parameter values (i.e. nugget, sill, and range) to ensure the robustness of the best fitting models. Universal kriging with trend was then performed, predicting soil Pb concentrations on a fine spatial grid for visualization, and at the residential locations of the study subjects for epidemiological analysis. Standard errors of predictions were retained and checked.

Statistical Analysis.

Exploratory analyses were conducted to describe pre- and postnatal tooth Pb and As concentrations by child, home and environmental characteristics. Unadjusted relationships between teeth metal concentrations and child characteristics were explored. Model fit was evaluated using residual plots, log likelihood tests and Aikake's Information Criteria. The final generalized linear models controlled for batch and maternal education. Intraclass correlation coefficients (ICC) were calculated to determine the agreement in Pb and As levels between teeth shed from the same child. The analyses were conducted in STATA IC 14 (College Station, TX) and R version 3.5.0.

Results and Discussion

Characteristics of the study population.

There were 50 teeth analyzed from 43 children who lived their entire lives in the study area. Table 1 shows the demographics of the study population. Of the 43 participants, 24 were female and 19 were male. All identified as Latina/o. The median year of birth among the participants was 2007, resulting in a median age of 9 (range of 7–18 years) at time of enrollment. The majority of the guardians who completed the interview preferred Spanish (77%). Participants were distributed across 4 adjacent residential neighborhoods: Boyle Heights (26%), Commerce (16%), East LA (28%), and Maywood/Huntington Park (30%). Of the mothers of children who donated teeth, 19 did not complete high school, 13 are high school graduates, and 11 attended at least some college. Approximately 40% (n=17) of households reported having someone living in their home during pregnancy and early childhood that worked in a profession that may have Pb exposure hazards, such as automobile repair (n=3), house construction (n=10) or welding (n=4). No mothers reported

working in any of these professions. Nearly all children (42/43) in the study lived in a home built before 1978 and 34 lived in a home built before 1950. The median home was built in 1939, with a range from 1912 to 2000. Four participants reported having any exposure to smoking inside the home during and after pregnancy. More mothers reported using formula or a mix of formula and breast milk (n=31) than having exclusively breastfed (n=12). No one reported using traditional medicines known to contain Pb (e.g. azarcon or greta).

Level of metals in teeth of the study population.

The mean prenatal Pb concentration in teeth samples, reported as a ratio $^{208}\text{Pb}:^{43}\text{Ca}$, was 4.104×10^{-4} (SD 4.123×10^{-4}), and the mean postnatal $^{208}\text{Pb}:^{43}\text{Ca}$ level was 4.109×10^{-4} (SD 3.369×10^{-4}) (Table 1). The 50th percentile of prenatal Pb was 2.480×10^{-4} with an interquartile range of 2.580×10^{-4} . The 50th percentile of postnatal Pb was 3.030×10^{-4} with an interquartile range of 4.050×10^{-4} . Overall, females had higher teeth Pb levels compared to males (p=0.10), and children of mothers with a high school education had significantly lower teeth Pb levels (p=0.005).

We observed a high Pearson's correlation between prenatal and postnatal $^{208}\text{Pb}:^{43}\text{Ca}$ (r = 0.87). Among children with two teeth (n=7), the intraclass correlation for prenatal Pb was 0.98 and 0.88 for postnatal Pb, suggesting high correlations within teeth from the same individuals and supporting the robustness of our laboratory method.

Of the 43 children, 20 had detectable prenatal and 17 had detectable postnatal As concentrations in their teeth. Among the teeth in which As was detected, the mean prenatal level (n=20) was $0.298 \times 10^{-4} \text{ } ^{75}\text{As}:^{43}\text{Ca}$ (SD 0.204×10^{-4}) compared to 0.22×10^{-4} (SD 0.160×10^{-4}) for mean postnatal level. There were 15 children with detectable arsenic in both time periods, and the pre- to post-natal correlation was 0.62.

Soil Pb estimates in the community.

Among all soil samples from the study area, the median soil Pb concentration was 190 ppm with a range of range 1 – 73200 ppm. There were 13.7% (n=16066) samples that exceeded 400 ppm and 1.7% (n=1972) that exceeded 1000 ppm. The concentrations were highly right skewed, with median concentration of the 7,697 sample locations used in the spatial analysis equal to 269.9 ppm (IQR = 219.8 ppm). Given the skew, concentrations were log transformed. The Gaussian spatial covariance model performed best (SSE=2648), with an estimated spatial range of 1213 meters (Figure S1). Universal kriging with a linear trend was conducted, predicting Pb in a grid (Figure S2) and separately at the residential locations of the study subjects. Predicted concentrations assigned based on participant pregnancy and birth address ranged from 157 ppm to 403 ppm.

Unadjusted association between teeth metal levels and demographic characteristics.

In the unadjusted models (Table 2), both children of mothers with less than a high school education and soil Pb exposure are statistically significant (p<0.05) predictors of higher prenatal and early life teeth Pb levels. Males, on average, had lower levels of teeth Pb compared to females, but this difference is not significant. Other characteristics including living near a freeway (<300 m), being exclusively breastfed, having a household member

that works in a potentially Pb-exposed occupation, a house built prior to 1950 or living with a smoker are not significant predictors of teeth Pb.

Association between teeth Pb levels and soil Pb levels.

In unadjusted models both pre- and post- natal teeth Pb levels are significantly associated with soil Pb levels (p-value of 0.002 and 0.03, respectively) (Figure 2). After adjusting for maternal education and batch, we observe positive associations between teeth Pb per 100 ppm increase in soil Pb. In prenatal teeth, the association is statistically significant ($\beta=3.48$, 95% CI 1.11, 5.86) and in postnatal teeth the association is slightly attenuated compared with the pre-natal levels ($\beta=1.91$, 95% CI -0.05 , 3.87), with a p-value of 0.056. Higher maternal education remains a significant protective factor in the adjusted models.

While gender is not statistically significant on its own, it is significant in the adjusted model, with boys having lower teeth Pb than girls ($\beta=-2.67$, 95% CI -4.92 , -0.42) adjusted for maternal education and batch. Furthermore, gender is a significant modifier of the soil Pb association, suggesting that among this sample, boys and girls have different soil Pb uptake, with a significant positive association for girls and a flat association for boys that is not significantly different than zero.

We further adjusted the model to include an indicator for detectable teeth As. On average, prenatal teeth Pb was 2.5×10^{-4} (95% CI 0.20, 4.80) units higher among children that had detected arsenic in their teeth, with a similar postnatal effect in early childhood (Table 3).

Research and Policy Implications.

Disproportionate exposure to toxic chemicals is a burden faced by working class communities of color across the United States.²⁹ Chronic exposure to low levels of Pb is still a significant public health issue, particularly among people of color and other marginalized communities where housing stock is older, increasing the risk of Pb in paint or water pipes, and where people are more likely to live near industrial sources.⁶⁵³⁰ Earlier research on chronic low-level Pb exposure using baby teeth as biomarkers demonstrated disproportionate exposure among low-income and children of color,³¹³² however these studies could not identify when these observed disparities began. In this study, we characterize prenatal and early childhood Pb and As exposure using dentine. Our results corroborate earlier findings, in that we observe that exposure to Pb is associated with higher tooth Pb concentrations in this population of low-income and Latino children living near an industrial Pb smelter.

Lead production has long been associated with community harm and adverse health effects of workers. Historical records as early as the 1890s show farmers complaining about dust emissions, contamination of streams, and harm to livestock from smelters.⁹ In the 1970s, research demonstrated extremely high prevalence of childhood Pb poisoning among those living near and working in US Pb smelters,¹⁰⁻¹² Among children living near a smelter in Australia whole-tooth Pb levels were inversely correlated with intellectual development at age 7.³³ More recently, a study of children living near a smelter in Mexico identified that soil Pb levels and level of education were significant predictors of blood Pb levels.³⁴

An estimated 3,500 tons of Pb have been released by this smelter during its last 30 years of operation.¹⁴ The residential communities nearby are more than 90% Latino and rank among the top 10% of the most environmentally burdened neighborhoods in California.³⁵ In this study we found a median soil Pb concentration of 190 ppm with nearly 14% of surface soil samples exceeding 400 ppm. By comparison, a study across central Los Angeles County focused on near freeway soil sampling found a median of 81 ppm with 8% of samples exceeding 400 ppm.³⁶ We still identify an association between soil Pb levels with both in utero and early life exposure to Pb despite observing neighborhood-averaged soil Pb concentrations < 400ppm.

Lead contaminated soils may be transported inside the home via soil resuspension³⁷ or tracked inside attached to shoes or on the feet of pets³⁸ and thus can be an important contributor to household dust.³⁹ Based on a review of previous studies, Jin et al (1997) concluded that compared to children exposed to soil Pb levels of 100 ppm, among children exposed to 1000 ppm, 9–46% of the blood-Pb levels could be attributed to the excess soil lead exposure. Others have also demonstrated that the contaminated soil contribution to the blood Pb burden in children^{40,41} and the resuspension of soil Pb are significant sources of exposure.⁴²

Lead can cross the placenta during pregnancy⁴³ and has been associated with a range of adverse birth outcomes including small-for-gestational-age,⁴⁴ stunted childhood growth⁴⁵ and impaired cognitive functions.^{46,47,48} Previous work in South Carolina found associations between soil Pb at maternal residences during pregnancy and intellectual disabilities and low birth weight in children.⁴⁹ The combined effect of Pb and As in soil was also found to be associated with significantly increased odds of several intellectual disabilities in these children.⁵⁰ In this cohort, we observe a statistically stronger association between soil Pb and *in utero* teeth Pb levels compared to early childhood. This may, in part, be explained by a cumulative Pb burden in women living in these urban industrial communities that is passed to the fetus,⁵¹ and higher levels prenatally, as measured by baby teeth, have been observed elsewhere.²⁴ Infants' Pb exposure may have been influenced by other factors not fully captured in this model, like hand to mouth behaviors or feeding practices.^{52,53}

We present a community-based pilot study that has a small sample size and therefore some limitations but is novel and offers several unique features. Through LA-ICP-MS techniques we were able to distinguish prenatal and early life Pb exposure. Since there is limited population-level data on lead concentrations in baby teeth, we are unable to compare our findings with nationally representative levels. We observe similar levels in our cohort to those in a cohort of children in Mexico City, where Pb levels in environmental and biological media are, on average, higher than what is seen in the US.²⁶ Compared to a cohort in Sweden, we find higher teeth Pb levels on average in children in this community.⁵⁴ We have detailed characterization of soil Pb levels measured in 2015–2017 around the residential location of our study population, which is a valuable source of exposure data but requires us to assume that these concentrations are representative of the soil Pb concentrations during both in utero and early childhood periods of the participants. To the best of our knowledge, soil Pb data in residential neighborhoods are not available prior to 2015. Since individual soil Pb measurements can be highly variable even within one

property, we used kriging interpolation to assign exposure levels, an approach taken by others⁵⁵ that provides a spatially weighted average estimate at the residential locations of study participants. We were unable to account for about the mother's activity patterns (e.g. time spent outside in the yard) or child's hand-to-mouth behavior that may influence exposure.

The Truth Fairy project provides further evidence that environmental injustice is vertically transmitted from mothers to their unborn children and that this burden is disproportionately borne by disadvantaged communities. Measuring and assessing human exposure at legacy pollution sites is challenging, and misclassification of historical exposures is often a key obstacle in assessing the resulting health damages. Measurements in teeth provide a unique biomarkers to characterize and time-stamp historical environmental exposures.¹⁹ This biomarker further offers the opportunity to conduct retrospective exposure studies in a community-driven method.⁵⁶ Among participants, we identified soil Pb concentrations as an important predictor of teeth Pb levels. Legacy Pb contamination accumulated in soil may play an important role *in utero* exposures, suggesting remediation of soil Pb contamination is a key step to lessen Pb transmission between mothers and babies. Testing women during pregnancy, or even earlier as they enter child-bearing age, may also provide information to women and public health agencies about exposures. Our results have important implications for public health, especially for communities near industrial Pb sources, and suggest that elimination of Pb exposures, including legacy soil contamination, may be important to address existing health disparities.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

ACKNOWLEDGEMENTS

We thank the community organizations and residents for their collaboration and dedication to support health in their community; in particular, we are grateful to East Yard Communities for Environmental Justice and Resurrection Church. We further thank mark! Lopez, Jessica Prieto, Hugo Lujan, Laura Cortez and Cindy Donis.

Funding source

This research was supported in part by NIH/NIEHS 5P30ES007048.

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Figure 1.
Estimated soil Pb levels across the study area and approximate location of participants (shown by black squares).

Figure 2. Scatter plots and unadjusted regression lines of predicted soil Pb levels (ppm) and measured teeth Pb levels.

Table 1.Population Demographics of the Study Participants and Teeth Pb ($^{208}\text{Pb};^{43}\text{Ca} \times 10^{-4}$)

	Number	Prenatal	Postnatal
	N	Mean (SD)	Mean (SD)
Gender			
Male	19	2.99 (2.13)	3.59 (2.03)
Female	24	5.05 (5.12)	4.52 (4.14)
Year of Birth			
Before 2007	25	3.62 (2.88)	3.57 (2.29)
2007 or Later	18	4.87 (5.49)	4.85 (4.43)
Type of infant feeding			
Breastfeeding	12	4.73 (4.31)	4.16 (2.52)
Any formula	31	3.91 (4.12)	4.09 (3.68)
Occupational Exposure			
No	26	3.99 (4.50)	3.70 (3.67)
Yes	17	4.37 (3.72)	4.74 (2.83)
Level of Education			
No high school diploma	19	5.85 (4.73)	5.59 (3.84)
High school diploma	24	2.79 (3.13)	2.94 (2.44)
Near Freeway (< 300 m)			
No	29	4.58 (4.45)	4.42 (3.86)
Yes	14	3.23 (3.47)	3.45 (1.99)
In home Smoking			
No	38	4.35 (4.38)	4.19 (3.49)
Yes	4	2.66 (1.47)	3.64 (2.84)
Year of Home			
Pre 1950	34	4.00 (4.19)	4.15 (3.67)
Post 1950	9	4.67 (4.26)	3.94 (2.02)
Batch			
March	33	4.49 (4.56)	4.53 (3.64)
October	10	2.99 (2.23)	2.73 (1.79)
Neighborhood			
Boyle Heights	11	6.20 (4.75)	5.02 (3.09)
Commerce	7	2.83 (3.37)	3.71 (3.69)
East Los Angeles	12	4.54 (5.75)	4.32 (5.32)
Maywood/Huntington Park	13	2.89 (2.17)	3.37 (1.83)

Table 2.

Unadjusted and adjusted associations of covariates with prenatal and postnatal Pb tooth concentrations (^{208}Pb : $^{43}\text{Ca} \times 10^4$)

	PRENATAL		POSTNATAL	
	Unadjusted <i>Estimate (95% CI)</i>	Adjusted ^I <i>Estimate (95% CI)</i>	Unadjusted <i>Estimate (95% CI)</i>	Adjusted ^I <i>Estimate (95% CI)</i>
Male (vs female)	-2.06 (-4.51, 0.40)	-2.67 (-4.92, -0.42) **	-0.93 (-2.97, 1.10)	-1.47 (-3.29, 0.36)
Maternal high school graduate (vs not)	-3.06 (-5.42, -0.71) **	-3.16 (-5.51, -0.81) ***	-2.65 (-4.54, -0.76) ***	-2.76 (-4.60, -0.92) ***
Born after 2007 (vs before)	1.25 (-1.28, 3.77)	1.37 (-1.01, 3.75)	1.28 (-0.74, 3.30)	1.33 (-0.52, 3.18)
Breastfed Only (vs some formula)	0.81 (-1.98, 3.61)	0.24 (-2.42, 2.91)	0.08 (-2.20, 2.35)	-0.43 (-2.52, 1.65)
Any occupational exposure (vs none)	-0.38 (-2.96, 2.19)	0.069 (-2.37, 2.50)	-1.04 (-3.10, 1.02)	-0.66 (-2.56, 1.24)
Live Near (< 300m) Freeway (vs away)	-1.35 (-4.00, 1.31)	-1.49 (-4.06, 1.09)	-0.97 (-3.12, 1.18)	-1.20 (-3.22, 0.82)
In home smoker (vs none)	-1.64 (-5.94, 2.67)	-0.95 (-5.03, 3.13)	-0.52 (-4.03, 2.99)	0.10 (-3.10, 3.31)
First batch (vs 2nd)	-1.50 (-4.45, 1.44)	-1.74 (-4.50, 1.02)	-1.80 (-4.15, 0.55)	-2.01 (-4.17, 0.15)
Soil Pb Levels (100 ppm increase)	3.95 (1.46, 6.43) ***	3.48 (1.11, 5.86) ***	2.35 (0.23, 4.47) **	1.91 (-0.05, 3.87) *

^I Adjusted for maternal education and batch.

*
p<0.10

**
p<0.05

p<0.01

Table 3.

Measured Arsenic levels in Teeth ($^{75}\text{As}:^{43}\text{Ca} \times 10^{-4}$).

	Arsenic	N	Predicted Soil As (ppm)	Teeth As	Predict Soil Pb (ppm)	Teeth Pb
Prenatal	Detected As	20	5.79 (0.65)	0.30 (0.20)	272 (48)	4.71 (4.76)
	As <LOD	23	5.57 (0.79)	--	292 (43)	3.65 (3.60)
Postnatal	Detected As	17	5.92 (0.49)	0.25 (0.16)	284 (50)	5.17 (3.92)
	As <LOD	26	5.52 (0.82)	--	282 (45)	3.41 (2.81)