LEAD DISTRIBUTION IN URBAN SOILS: RELATIONSHIP BETWEEN LEAD SOURCES AND CHILDREN'S BLOOD LEAD LEVELS

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DEDICATION

To the pillar of my life: my daughter, Noelle.

The road we chose was definitely the one less traveled by and with the help of our guiding angel, Hoda, this road has made all the difference.

It is a privilege to be your mother and to watch you grow from that curious little girl who couldn’t get enough of the ocean, pool or anything else water related to a wonderful, beautiful, intelligent, young woman and diver.

From you is where I draw my strength and inspiration. I am the luckiest mother in the world. I love you my Noey.

Just remember to always keep swimming, swimming, swimming…..

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1.0 INTRODUCTION

Due to its high density, malleability, low melting point and other desirable chemical properties, lead (Pb) has found its way into many applications throughout history including make-up additives, writing instruments, pipes, ceramic dishes, storage tanks, paint and gasoline (automotive and jet-fuel) (ATSDR 2007; Filippelli et al. 2005; Mielke et al. 2003). Once Pb is released into the environment through anthropogenic sources it remains in the upper layer of the soil for extended periods of time and becomes bioavailable to humans (ATSDR 2007; Chaney et al. 1989; Mielke et al. 2003). The last century has produced study after study proving that soil Pb is not only persistent in the environment, but also dangerous as adults and children are adversely affected when Pb is absorbed into the body (Chaney et al. 1989; Laidlaw et al. 2005). The relationship between soil Pb and children's blood lead levels (BLLs) has been recently highlighted as a result of Hurricane Katrina. After the flooding in New Orleans, the median level of Pb in the soil went from 329 to 203 ppm (38.3% drop) which corresponded to a 33% decrease in children's BLLs (Zahran et al. 2010).

1.1 Sources of Lead

The main sources of Pb to urban soils are Pb-based paint, Pb additives in gasoline and industrial sources (Chaney et al. 1989; Filippelli et al. 2005; Laidlaw et al. 2005; Mielke et al. 2003). The legacy of Pb deposition is not uniform, with urban soil Pb loading being particularly high due to the concentration of traffic volume, housing, and industrial facilities (Filippelli and Laidlaw 2010; Filippelli et al. 2005; Mielke and

Reagan 1998; Mielke et al. 2003). Urban concentrations of soil Pb are typically several orders of magnitude higher than background values, and values tend to be greatest near legacy sources like roadways, Pb-painted structures and Pb smeltering facilities (Filippelli et al. 2005). These legacy sites become prime factors in Pb exposure to humans, and Pb poisoning in children (Filippelli et al. 2005; Mielke et al. 2003).

1.2 Epidemiology

Children exhibit more severe Pb toxicity than adults due to their higher metabolic rates, rapid growth, developing neural systems, and hand-to-mouth behavior (ATSDR 2007; Chandramouli et al. 2009; Gaitens et al. 2009). Ingestion is the major route of exposure for children where up to 50% of the Pb ingested is absorbed in the gut and subsequently about 73% of absorbed Pb is stored in the bones (ATSDR 2007). Lead that is stored in the bones is released back into the blood stream as the bones regenerate over time, thereby providing a continued source of chronic Pb exposure (ATSDR 2007; Centers for Disease Control and Prevention (CDC) 1992; Chandramouli et al. 2009). Those children who have BLLs above 10 µg/dL exhibit a wide range of negative physiological effects including hypertension, hearing difficulties, stunted growth, vomiting, colic, anemia, encephalopathy, nephropathy, bluish discoloration of the gums and even death (ATSDR 2007; CDC 1991, 1992; Reeder et al. 2006). Behavioral effects of Pb in children include Attention Deficit Hyperactivity Disorder (ADHD), mental retardation, learning disorders, lower IQ's, as well as delinquent behavior (Chandramouli et al. 2009; Federal Interagency Forum on Child and Family Statistics (FIFCFS) 2010;

Lanphear et al. 1996; Needleman et al. 2002). Treatment of children with high BLLs includes removal the child from the source(s) of Pb exposure, nutrition counseling, and in more severe cases the use of chelating agents to mobilize Pb in the body for removal through urine and feces (CDC 2007; Chandramouli et al. 2009). Socioeconomic factors including age, low economic status, poor education, poor nutrition, and lack of health resources also affect the level of Pb found in the body. (Lanphear et al. 1996).

The removal of Pb from Pb-based paints and Pb in gasoline from the environment has corresponded to a significant drop in children's BLLs. Although the use of Pb in paint and gasoline was phased out (1978 and 1986, respectively), the legacy of nearly a century of deposition of the Pb from these sources into nearby soils and atmospheric re-suspension of these soils still produces many adverse health effects in the areas where people live, work and play (Filippelli and Laidlaw 2010; Laidlaw and Filippelli 2008; Mielke et al. 1997). In 1991, approximately 250,000 children from ages 1 to 5 in the United States alone still had elevated BLLs (defined as a level ≥ 10 μg/dL), which prompted US Department of Health and Human Services to set a national "Healthy People 2010" goal that no child in the US would have an elevated BLL (CDC 2010). The geometric mean of BLLs for children ages 1–5 decreased from 14.9 μg/dL in 1976–1980 (with 88% ≥ 10 μg/dL) to 1.5 μg/dL for the years 2007–2008 (with 0.9% ≥ 10 μg/dL (US EPA 2010). The action level for intervention was lowered from 60 μg/dL in the 1960's to 10 μg/dL in 1991 (CDC 1991). Evidence has shown that there are significant and numerous adverse health effects with levels lower than the current action limit of 10 μg/dL (Gould 2009; Jusko et al. 2008; Zahran et al. 2009).

While the reduction of Pb poisoning cases is considered one of the most stunning examples of a public health success (Silbergeld 1997), the unfortunate truth is that there is still an unequal distribution of Pb poisoning cases in the US (Gould 2009). Since urban soils tend to have higher concentrations of Pb, social injustice facing those populations who inhabit urban older cities is rampant (Lejano and Ericson 2005). Lead poisoning is completely preventable, yet multiple factors (sex, income, race, nutritional status and location of primary residence) are associated with increased exposure rates among residents in communities with higher burdens of Pb contaminated soils (CDC 2010; Filippelli et al. 2005; Silbergeld 1997).

Children with the greatest prevalence of BLLs ≥ 10 μg/dL are non-Hispanic black and Mexican American children, and those children from low income urban areas with older housing (CDC 2005). Specifically, during the years 1988–1994, non-Hispanic black children were reported to be three times more likely to have BLLs between 6-9 μg/dL, seven times more likely to have BLLs between 10-20 μg/dL, and 13 times more likely to have BLLs > 20 μg/dL than non-Hispanic white children (Bernard and McGeehin 2003). The percentage of children with elevated BLLs for the years 2005-2008 is not available; however 3% of children exhibited levels ≥ 5 μg/dL with the highest frequency among non-Hispanic blacks at 7% (a decrease from 19% in 1999-2002) (FIFCFS 2010).

1.3 Purpose and Scope

Prior research has shown a direct relationship between diffuse soil Pb in Marion County, Indianapolis, Indiana and elevated children's BLLs. There is a "bulls-eye" pattern showing the highest concentration at the urban center, and gradually decreasing soil Pb levels further out but still elevated near downtown residential communities (Filippelli et al. 2005). In 2008, Marion County had a population just over 876,000 with 32.5% being minority and average per capita income $25,546 (US Census Bureau 2008). The majority of minority children live in the lower income, urban areas of Marion County. Given the financial and logistical burden to remediate soil with elevated Pb on a city level, it is proposed that if the same direct relationship between BLL and soil Pb holds true for smaller communities then remediation could be targeted in areas with greatest needs. In order to test this hypothesis, the Westside Cooperative Organization (WESCO) located in the 46222 zip code of Marion County, Indianapolis, Indiana was chosen to determine whether a spatial relationship exists between low dose chronic exposure to elevated soil Pb and elevated BLLs on a smaller, neighborhood scale as opposed to large county wide scale. This area was chosen for study as the majority of residents are minority, low income, and living in older homes (many pre-1920's). Additionally, WESCO has a history of elevated BLLs as a direct result of previous Pb industry located in the southern portion of the neighborhood. WESCO also has an interest in environmental and urban renewal. Using BLLs in the WESCO area from existing medical records and a year-long filter pilot study we assessed if there is a relationship between interior dust, immediate vicinity soil Pb and children's BLLs.

2.0 MATERIALS AND METHODS

2.1 Soil Samples

Approximately 266 soil samples were collected (December 2007 to August 2009) from within the WESCO study area. Soil collection techniques involved a pooled sample of the upper 5 cm of soil from a one-square foot area of each site with each sample geolocated. Samples were dried overnight at 110°C and sieved to < 63 micron fraction and then weighed and ashed at 550°C for two hours and re-weighed, to determine organic matter content by Loss-on-Ignition (LOI). After ashing, the residue was digested at room temperature in 50 mL HDPE disposable centrifuge tubes for 24 hour in 2N trace metal grade hydrochloric acid on a shaker table. Following digestion, samples were then centrifuged at 9,000 rpm for 10 minutes. Samples, blanks and certified consistency standards were analyzed in triplicate using Leeman Labs PS 950 inductively coupled plasma-atomic-emission spectrometry (ICP-AES) coupled with a CETAC AT5000+ ultrasonic nebulizer.

2.2 Filter Samples

Seven households agreed to take part in the filter analysis study. At each home new 3M Filtrete MPR (micropartial performance rating) filters were installed. Starting in December of 2007 and every two months thereafter for one year, the new filters were placed in the homes. All filters were processed using an investigational digestion technique that involved removing the cardboard frame and wire supports. For each filter set, a clean, unused blank filter was processed and analyzed. Filters were then cut into two inch wide strips, weighed, dried overnight at 110°C and reweighed and secured in plastic jars. Digestion of the filters involved initial removal of grease and oil residue with ethanol and overnight shaking. The ethanol was evaporated, and then 100 mL of 2N trace metal grade hydrochloric acid and 2 mL of hydrofluoric acid were added, and the digestion vessels were shaken for 72 hours. The extractant was then filtered using Whatman 2.5 μm particle retention filter paper, and 0.5 g of boric acid was added to stabilize the extractant-this mixture was then shaken overnight. The filters were processed and analyzed in triplicate along with NIST standards using Leeman Labs PS 950 ICP-AES coupled with a CETAC AT5000+ ultrasonic nebulizer.

2.3 Study Population

In order to study the effects of neighborhood Pb levels in soil and its relationship to children's BLLs, data were mined using the Regenstrief Medical Record System (RMRS). The RMRS, known internationally as one of the largest electronic medical records database, has been in operation since 1973 and has over 660 million distinct observations from several of the major hospital systems and affiliated clinics in the Indianapolis area (http://www.regenstrief.org/ medinformatics/rmrs). The research protocol was approved by the IUPUI/Clarian Institutional Review Board. Children between the ages of 0-5 during the years 1999-2008 with a recorded address in Marion County and at least one serum Pb level (measured in μg/dL) rmeasured were included. Other data collected included serum hematocrits, race/ethnicity, insurance status (as a proxy for income), date of serum Pb test, and the child's age at the time of testing.

Testing months were broken down into seasons as follows: winter (December, January, February), spring (March, April, May), summer (June, July, August), and fall (September, October, November). The geometric means, averages and percentages were generated using SAS software, Version 9.1 (SAS Institute Inc. 2002-2003). Relative risk ratios, confidence intervals and p-values were generated using EpiInfo Version 6.0 (1993). Risk ratios in this research are defined as the risk of a child having an elevated BLL in one group relative to another group.

2.4 US Census/Tax Assessor Data

To assess for differences in demographic data including race, and children under age five as a percentage of both US Census block and block group were mapped by zip code using the available 2000 Census data. Additionally, the age and addresses of residential homes in the WESCO area were accessed from the Marion County Tax Assessor's office. Area level data on housing age was calculated by averaging these data by US Census block and block group and mapped.

2.5 Spatial Analysis

In order to map the average BLLs for the children in the dataset, patient records from RMRS were geocoded using ARCMap®9.2 (ESRI 2009). Street names, locations, and address numbers were mapped using topologically integrated geographic encoding and referencing (TIGER) census street data. Exclusion criteria for eliminating children were missing address data, addresses outside Marion County, P.O. Boxes, or who did not have BLL results. Addresses were then mapped to their corresponding US Census block and block group. For the time period January 1999-January 2002 BLLs lower than 10 μg/dL were recorded categorically as “< 10” and were therefore excluded from means and analyses requiring continuous variables. Continuous BLL data were available for the time period February 2002-December 2008 and were used for the geospatial analysis. Inverse distance weighting (IDW) was used for soil Pb spatial interpolation.

Given the complexity of geographic data and in order to rapidly visualize patterns in BLLs in the WESCO neighborhood, the spatial interpolation technique method used was ordinary default kriging. The benefit of using interpolation techniques is that it allows trends to be mapped without acquiring samples from every point in an area and can reveal potentially high levels that have yet to be physically sampled. Default kriging maps were translated into averages for each zip code, US Census block, and/or US Census block group in Marion County. Prediction error map was created and used to compare against the sample standard deviation. If the standard error is larger than the original sample standard deviation this will result in unreliable kriging maps. Also mapped were the proportions of children with ≥ 10 μg/dL for each US Census block group.

3.0 RESULTS

3.1 Soil Samples

The average concentration of soil Pb for 266 samples taken was 259 ppm with a high (8119 ppm) taken outside the former Avanti Super Fund site (Figure 1A). The average Pb soil value inside the remediated Super Fund site was approximately 119 ppm. Hotspots of higher concentrations were found in areas just north of the remediated Super Fund site as well as along the Michigan Street corridor (Figure 1A).

3.2 Filter Samples

Of the seven homes that were included in the long-term pilot dust sampling (Figure 1B), one home was in the area that was remediated as part of the Avanti Super Fund site in the 1990's. Although filter testing was carried out every two months over the course of year, it was determined that the months of November, December, and January were the only months where the home owners ran their furnace consistently and therefore the only data points entered into the regression analysis. After removing the study home that was located in the remediated Super Fund area, regression results show that 57% of the variation of Pb dust (µg/g) in the home could be explained by the amount Pb in the surrounding soil (Figure 2). This is an important finding highlighting that this technique appears to be a useful alternative to ascertain the interior dust loading in homes and that local soils play a big role in the amount of Pb dust migrating into the home.

3.3 Study Population

A total of 16,232 records for the years January 1999-December 2008 were used for categorical analyses. Approximately 14% of all children in Marion County live within the 46222 zip code (n=2260) and 50% of children in the 46222 zip code live in WESCO (n=1143). The percentage of all children tested with ≥ 10 µg/dL was approximately 4.3% with the study area of WESCO exhibiting a higher rate of 7.7% (Table 1). Tables 1 and 2 show the increase in percentages of children with elevated BLLs and averages and geometric means as you move from the large geographic scale of the Marion County to the smaller zip code of 46222 and finally to the neighborhood of interest (WESCO). The average age of subjects at testing was 22 months with the youngest patient being one month old. Mean serum hematocrit level was 36 and appears not to be significantly associated with BLLs ($p > .05$).

The total number of patients available for continuous data analysis was 12,431 (for period of February 2002-December 2008). Averages and geometric means as well as comparisons to the National Health and Nutrition Examination Survey (NHANES) data are shown in Table 3. The WESCO neighborhood has a higher geometric mean, averages and percentage of children with BLLs ≥ 10 µg/dL as compared to Marion County children and zip code 46222 (Figure 3). Temporal trends from 1999-2008 using the percentage of children with elevated BLLs show an overall decrease for Marion County (Figure 4). As demonstrated with other studies, the children in this study exhibit higher BLLs during the hot, dry summer months and lowest in the colder months (for Marion County and WESCO neighborhood; however for reasons unknown, this relationship doesn't hold true for zip code 46222) (Laidlaw et al 2005; Yiin et al. 2000) (Figure 5). Children ages 31-60 months were at a 1.83-1.86 increased risk (when compared to other age groups) of having an elevated BLL across all levels (Table 3). In WESCO, 33.4% of those tested were classified as non-Hispanic black, 16% non-Hispanic white, and 47% Hispanic (compared to overall Marion County which is 88% White, 9% Black, and 4% Hispanic). In zip code 46222, non-Hispanic blacks were the only race that showed a 1.49 increased risk of having an elevated BLL (95% CI: 1.03-2.15) (Table 5). Males were at a 1.22 increased risk versus females on the county level (95% CI: 1.06-1.41). Those patients with commercial insurance were less likely to have elevated BLLs when compared to all others. Patients in the Wishard Advantage Program (for people with family income at or below 200% poverty level but who do not qualify for Medicaid) were at a significantly higher risk at all levels of having an elevated BLL, with WESCO Wishard Advantage patients having a 5.36 times greater risk (95% CI: 3.29-8.72) (Table 3).

3.4 US Census/Tax Assessor Data

According to the Marion County Tax Assessor's data, the oldest home in the WESCO area was built in 1849. Of the 5065 homes in WESCO, 89% of these homes were built before 1960 with the median home build year being 1920. The age of home appears to not be a contributor to BLLs due to the lack of variation in year built. Using US Census data, approximately 7.4% of the total population in Marion County is under the age of five years old and US Census block groups contain on average 6.9% children under the age of five. Only 8.4% of the 658 US Census block groups in Marion County have greater than 10% children under the age of five with the highest being 44%. All WESCO US Census block groups have 5-10% of the total population being children < 5 years old.

3.5 Spatial Analysis

Of the 16,232 (January 1999-December 2008) records used, 86% were matched during geocoding with a score of 80-100%, 5% were matched with a score of 60-80% and approximately 9% of the addresses were not able to be matched and subsequently mapped. The mean BLL of all children tested in Marion County by US Census block from February 2002-January 2008 were mapped (Figure 6A). The area at the center of the map shows lower BLLs due to the fact that very few children live in the downtown business district with the urban core exhibiting higher BLLs that decrease as you move towards suburban areas (Figure 6A). Averaged BLLs in the north central section of WESCO (> 5 μg/dL) exhibit higher BLLs than other areas in the same neighborhood (Figure 6B). The pattern of elevated BLLs for this area also reflects the neighborhoods racial breakdown with the same area being > 75% non-Hispanic black (Figure 6C). Prediction error map shows reliable kriging results with the root mean square 2.32 lower than the sample standard deviation of 3.36 (Figure 7). When mapping BLLs in Marion County by zip code for the period January 1999-December 2008, the greatest percentage of children with BLLs ≥ 10 μg/dL is located in the urban core and decrease further out (Figure 8). Using Chi-Square analysis comparing soil Pb and averaged BLLs for each

US Census block, the data available appear to show that there is not a significant correlation between BLL and soil Pb at the US Census block/neighborhood level.

4.0 DISCUSSION

Despite an increase in the number of children tested, there is a continual decrease over time of the geometric mean of BLLs due to the reduction of anthropogenic sources of Pb in the environment including Pb paint usage and Pb in gasoline as well as the closure of former Pb smelting industry (Figure 9). Given the homogeneity of the age of residential structures in WESCO, this variable was not considered substantial for inclusion in the analysis. The BLL data confirm past research showing that the urban core has higher geometric means as well as higher percentages of elevated BLLs. While the geometric mean for all US children is < 2 µg/dL (US EPA 2010), many Marion County children and subsequently WESCO children are still at levels much higher (Figure 10). In this study children ages 31-60 months are at increased risk of having elevated BLLs at both the county and zip code level though it appears the greatest risk factor for elevated BLLs in WESCO is race (non-Hispanic black) and not income or age of housing. When comparing the soil Pb and BLL values at the US Census block level, a direct relationship does not exist and confirmed pockets of elevated BLLs are not predicted by soil Pb levels. The factors that play a role in the children who exhibit elevated BLLs include their residence in the urban core of Indianapolis, race, and insurance status.

The pilot home filter testing study results show that proximal soil Pb concentrations around the homes account for almost 60% of the variation in the Pb dust inside on the filter. For the one home that had higher interior Pb but low soil Pb (the result of Super Fund soil removal), we suggest that (1) fugitive dust is still being emitted from the Pb-contaminated soils in and around the Super Fund site and/or (2) residual dust remains in the house and is being actively redistributed. Either of these scenarios lends caution to the assumption that the current model for soil remediation is adequate for protecting human health. Soil samples were collected in residential areas, not all yards were accessible and in these cases, roadside/curbside convenience samples were taken. Given that WESCO has a higher percentage of children under the age of five than the overall county, this could induce some bias in the results. Since approximately 92% of the study participants were on low-income insurance (Wishard Advantage, Medicaid), the results of the study also could be biased as those children from higher income families were not included in the analysis.

5.0 CONCLUSION

Data from the study confirm hotspots of elevated BLLs as represented by county wide mapping with the urban core posing the greatest general risk for children living in cities. The novel technique for examining interior house Pb loading proved successful both analytically and for identifying one site with remediated Pb but with obviously significant Pb loading from fugitive dust from the smelter's non-remediated areas. Additionally, soil Pb is correlated to interior Pb loading at least as identified within the constraints of the filter sampling. This investigation reveals that soil Pb and BLLs share high degree of variability at the neighborhood level (WESCO) with neither being predicted by the age of housing. While income was not a predictor of BLL variation, race indeed did emerge as an indicator for potential elevated BLLs.

Since 1999, the percentage of children who exhibit elevated BLLs has slowly decreased due to the removal of anthropogenic sources of Pb in the environment, however the current push to reduce the "action level" to < 5 µg/dL or even < 2 µg/dL (Zahran et al. 2009) means that many children will continue to be subject to the adverse effects of Pb in the environment with 64% Marion County children and 83% of WESCO children under the age of five with BLLs ≥ 2 µg/dL. Ultimately given that it has been reported that each dollar spent on lead prevention efforts produces $17-$221 in benefits including higher IQ, more tax revenue, lower spending on special education needs and less criminal activity (Gould 2009) targeting smaller areas such as neighborhoods for remediation would provide the most cost efficient way of reducing the adverse health effects of Pb in children.

Table 1. Demographic break-down of children less than the age of five who had a recorded BLL in the RMRS database for the period January 1999-February 2008 by % ≥ 10 µd/dL. ≥ 5 µg/dL, and ≥ 2 µg/dL. January 1999-January 2002.

Jan 99-Dec 08 Children Tested % ≥ 10 (µg/dL)

		Marion County	46222	WESCO
	All Children	4.32	4.9	7.65
Age	0-5 Months	0	0	0
	6-30 Months	3.57	4.12	6.41
	31-60 Months	6.68	7.74	11.88
Gender	Male	4.74	4.45	8.13
	Female	3.88	5.35	7.19
Race	Black	5.22	6.35	9.92
	Hispanic	2.98	4.53	7.69
	White	3.3	3.93	4.42
Insurance	Commercial	2.66	2.04	4.26
	Medicaid	4.39	4.54	6.88
	Wishard Advantage	7.33	25	34.21
	Self-Pay	4.71	0	-

Jan 99-Dec 08 Children Tested % ≥ 5 (µg/dL)

		Marion County	46222	WESCO
	All Children	13.79	19.71	27.27
Age	0-5 Months	11.11	100	0
	6-30 Months	12.75	18.8	26
	31-60 Months	16.94	23.26	32.04
Gender	Male	14.48	19.79	27.75
	Female	13.06	19.64	26.82
Race	Black	16.3	20.78	26.53
	Hispanic	10.59	18.7	27.78
	White	18.34	16.67	23.68
Insurance	Commercial	11.91	17.39	23.53
	Medicaid	13.8	19.2	26.38
	Wishard Advantage	20.26	42.86	56.67
	Self-Pay	10	22.22	33.33

Jan 99-Dec 08 Children Tested % ≥ 2 (µg/dL)

		Marion County	46222	WESCO
	All Children	63.85	75.06	82.52
Age	0-5 Months	62.68	100	66.67
	6-30 Months	66.67	74.6	81.98
	31-60 Months	67.38	76.74	84.53
Gender	Male	64.65	76.04	84.21
	Female	63	74.06	80.91
Race	Black	73.57	81.28	86.12
	Hispanic	56.54	69.78	78.85
	White	65.74	86.34	89.47
Insurance	Commercial	52.8	67.39	82.35
	Medicaid	64.35	75.21	82.38
	Wishard Advantage	72.03	80.95	83.33
	Self-Pay	55	66.67	83.33

Table 2. Demographic break-down of children less than the age of five who had a recorded BLL in the RMRS database for the period February 2002-December 2008.

Feb 02-Dec 08 Average BLLs (µg/dL)

		Marion County	46222	WESCO
	All Children	2.76	3.45	4.28
Age	0-5 Months	2.11	2	-
	6-30 Months	3.14	3.32	4.03
	31-60 Months	2.63	3.96	5.17
Gender	Male	2.82	3.35	4.26
	Female	2.7	3.55	4.29
Race	Black	3.09	3.8	4.69
	Hispanic	2.41	3.33	4.26
	White	3.05	3.34	3.63
Insurance	Commercial	2.23	2.51	2.9
	Medicaid	2.76	3.33	4.04
	Wishard Advantage	3.87	9.33	11.7
	Self-Pay	3	2.93	3.72

Feb 02-Dec 08 Geometric Mean BLLs (µg/dL)

		Marion County	46222	WESCO
	All Children	1.81	2.32	2.9
Age	0-5 Months	1.37	2	-
	6-30 Months	1.78	2.27	2.79
	31-60 Months	2	2.55	3.3
Gender	Male	1.85	2.33	2.99
	Female	1.78	2.31	2.81
Race	Black	2.12	2.62	3.12
	Hispanic	1.56	2.11	2.76
	White	1.98	2.72	3.05
Insurance	Commercial	1.86	1.82	2.37
	Medicaid	1.43	2.3	2.84
	Wishard Advantage	2.3	4.46	5.68
	Self-Pay	1.51	2.06	2.63

Table 3. Comparison of survey data for the total number of patients available for continuous data analysis was 12,431 with the geometric mean BLL for those patients during the period February 2002-December 2008 and the reported CDC Fourth National Exposure Report.

		Geometric Mean in µg/dL			
	Survey/Study Years	NHANES (US EPA 2010*)	Marion County	46222	WESCO
Total	99-00	1.7	NA	NA	NA
	01-02#	1.5	2.02	2.19	2.27
	03-04	1.4	2.34	2.65	3.07
	05-06	1.3	2.00	2.56	3.27
	07-08	1.3	1.36	1.95	2.68
Age					
0-1 Years	99-00	NA	NA	NA	NA
	01-02#	NA	1.50	2.61	2.88
	03-04	NA	1.72	2.54	3.06
	05-06	NA	1.43	2.10	3.27
	07-08	NA	1.10	1.23	1.59
1-5 Years	99-00	2.2	NA	NA	NA
	01-02*	1.7	2.09	2.17	2.25
	03-04	1.8	2.40	2.66	3.07
	05-06	1.5	2.11	2.61	3.27
	07-08	1.5	1.40	2.06	2.80
Gender					
Males	99-00	2.0	NA	NA	NA
	01-02#	1.8	2.14	2.29	2.18
	03-04	1.7	2.41	2.57	3.13
	05-06	1.5	2.07	2.58	3.38
	07-08	1.5	1.35	1.99	2.91
Females	99-00	1.4	NA	NA	NA
	01-02#	1.2	1.93	2.06	2.39
	03-04	1.2	2.27	2.73	3.01
	05-06	1.1	1.93	2.53	3.19
	07-08	1.1	1.37	1.91	2.45
Race/Ethnicity					
Hispanic/Mexican Americans	99-00	1.8	NA	NA	NA
	01-02#	1.5	1.76	1.89	1.76
	03-04	1.6	2.05	2.60	2.87
	05-06	1.3	1.78	2.39	3.30
	07-08	1.3	1.15	1.70	2.62
Non-Hispanic Blacks	99-00	1.9	NA	NA	NA
	01-02#	1.7	2.30	2.23	2.56
	03-04	1.7	2.63	2.96	3.35
	05-06	1.4	2.37	2.98	3.56
	07-08	1.4	1.67	2.28	2.73
Non-Hispanic Whites	99-00	1.6	NA	NA	NA
	01-02#	1.4	1.99	2.94	2.77
	03-04	1.4	2.58	2.58	3.30
	05-06	1.3	2.23	2.68	3.08
	07-08	1.2	1.45	2.80	2.81

*US EPA (US Environmental Protection Agency). 2010.
#Data recorded for the time frame '01-02' for Marion County, 46222 and WESCO are for February 2002–December 2008 and therefore maybe be lower than expected.

Table 4. Risk ratios for children with elevated BLLs (≥ 10 g/dL) for the period January 1999-December 2008.

	Risk Ratios (95% Confidence Interval)		
	Marion County	46222	WESCO
0-5 months vs. All Others	+	+	+
6-30 months vs. All Others	.53# (.46-.62)	.55* (.37-.80)	.54* (.36-.82)
31-60 months vs. All Others	1.88# (1.62-2.18)	1.83* (1.25-2.68)	1.86* (1.23-2.81)
Male vs. Females	1.22# (1.06-1.41)	.21# (.07-.62)	1.12 (.75-1.67)
Non-Hispanic Blacks vs. All Others	1.30# (1.12-1.51)	1.49* (1.03-2.15)	1.47 (.98-2.20)
Non-Hispanic Whites vs. All Others	1.41# (1.19-1.67)	.81(.46-1.42)	.52 (.26-1.06)
Hispanic vs. All Others	.54# (.46-.64)	.82 (.57-1.19)	.98 (.66-1.46)
Commercial Insurance vs. All Others	.56* (.41-.85)	.62* (.43-.90)	.56 (.14-2.19)
Medicaid vs. All Others	1.14 (.88-1.47)	1.33 (1.00-1.78)	.42# (.25-.70)
Wishard Advantage vs. All Others	1.72* (1.19-2.47)	5.50# (3.29-9.18)	5.36# (3.29-8.72)
Self-Pay vs. All Others	1.08 (.42-2.83)	+	+

*p <.05
#p <.001
+Not enough observations to get reliable estimate

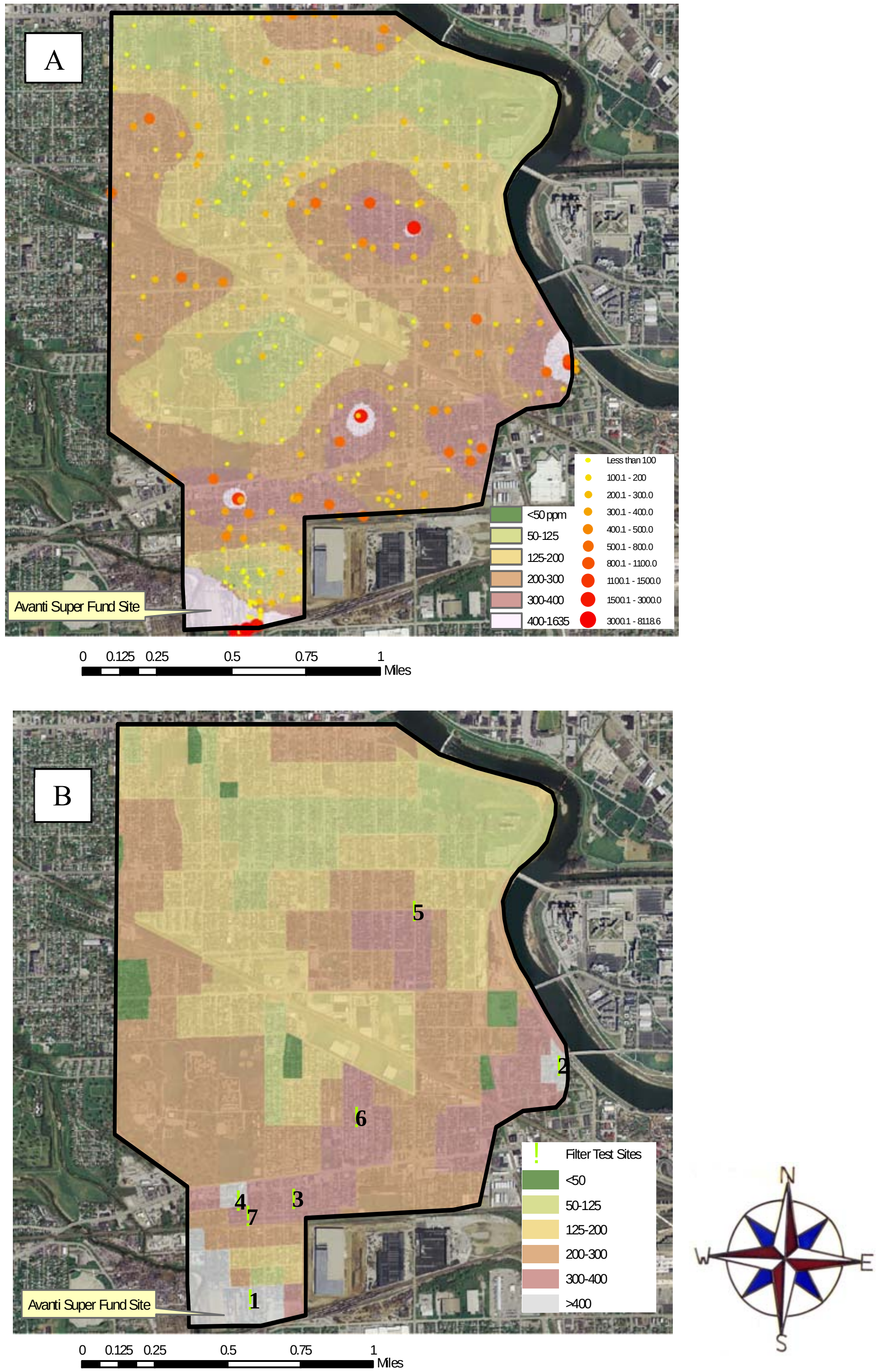

Figure 1. Inverse distance weighted map (IDW) of WESCO showing actual sampling points (1A). This map was then contoured and smoothed every 25 feet and averaged into US Census blocks with sites of long term filter testing shown (1B).

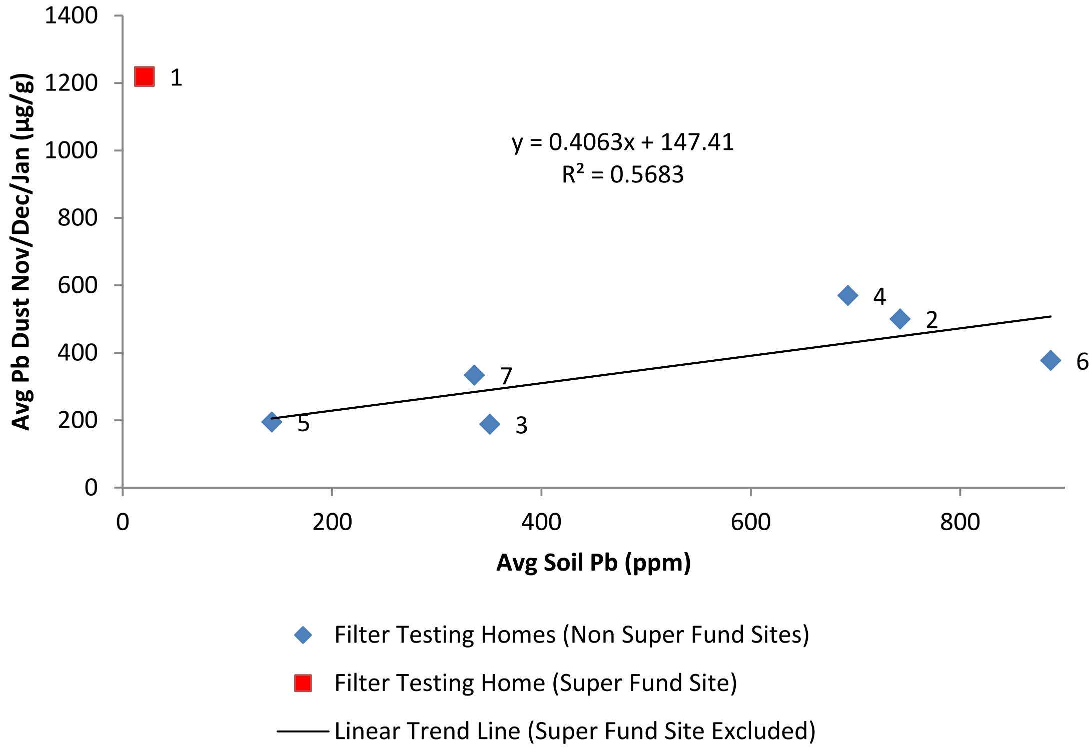

Figure 2. Interior filter dust versus Pb dust surrounding the seven homes that took place in the yearlong filter study. Home 1 was excluded from the linear regression due to the fact it is located in the area that was remediated as an EPA Super Fund site.

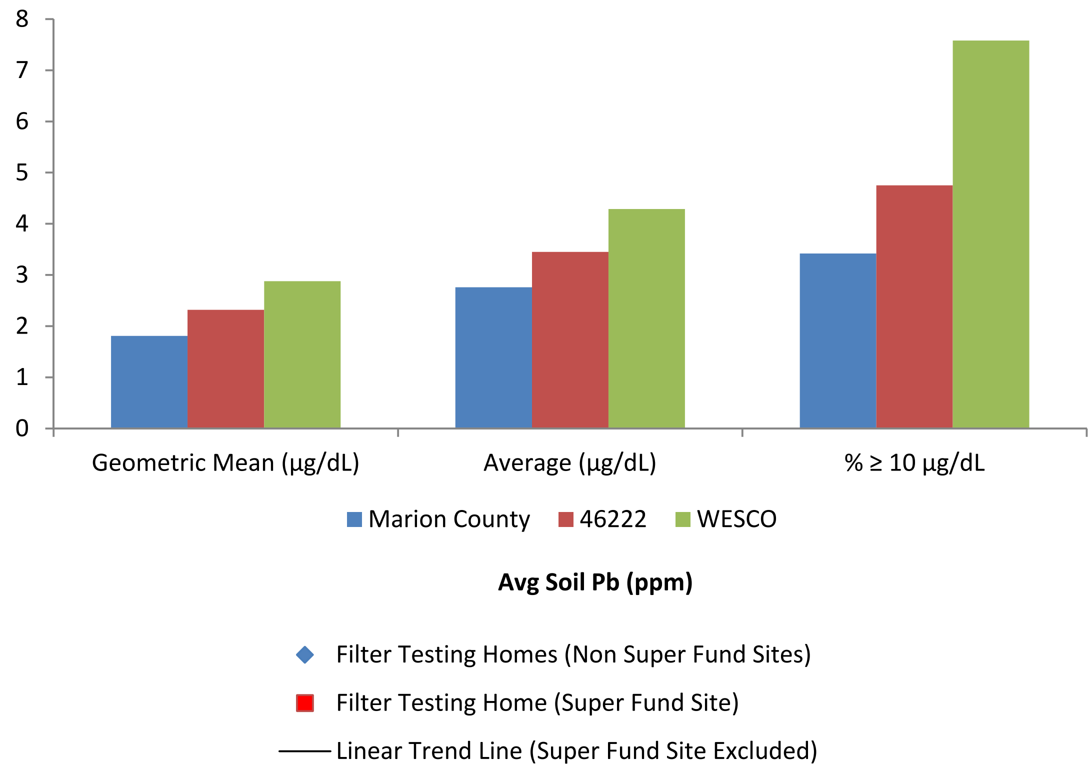

Figure 3. Overall geometric mean and averages for all children in the study for the period February 2002-December 2008 and percentage ≥ 10 µg/dL for the period January 1999-December 2008.

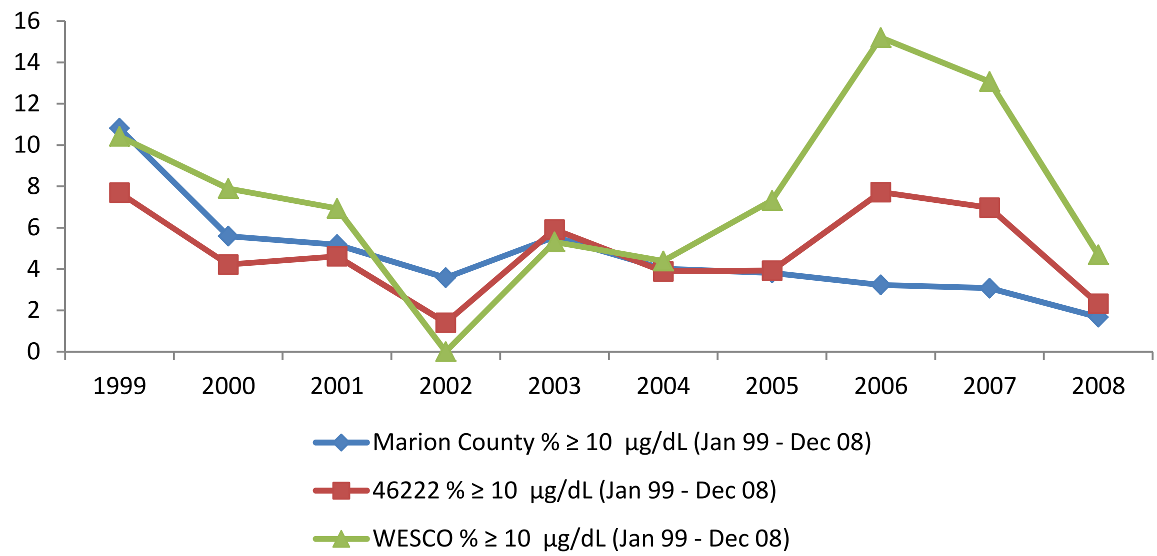

Figure 4. Percentage of children with ≥ 10 µg/dL by county, zip code and neighborhood for the study period January 1999-December 2008.

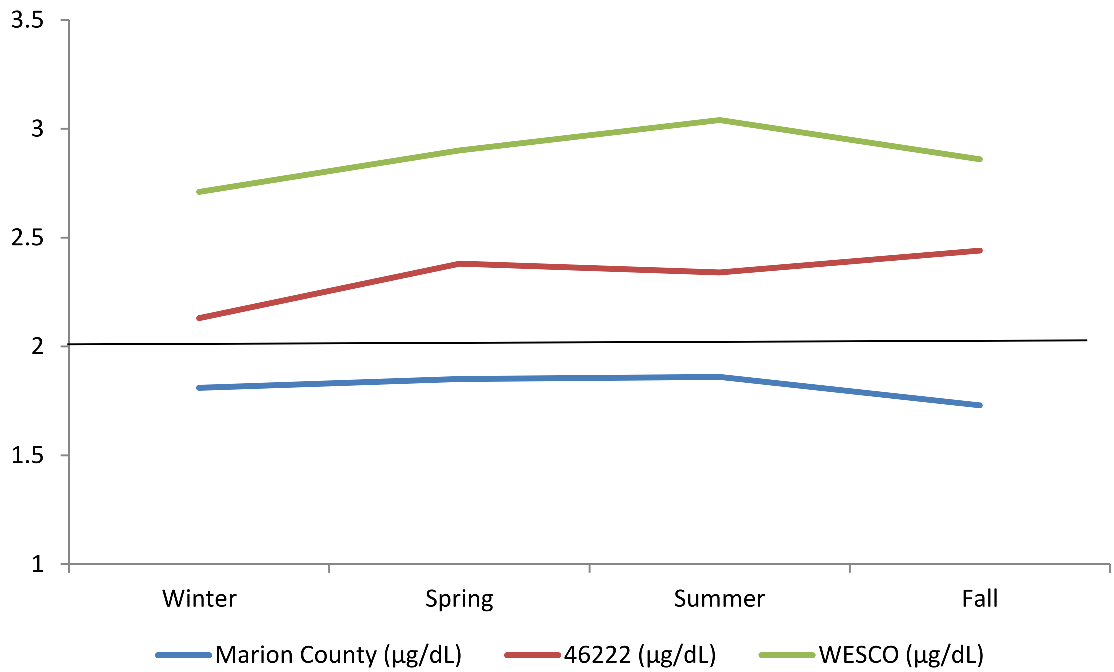

Figure 5. Geometric means classified by season. Overall Marion County is below the proposed action level of ≥ 2 µg/dL, while zip code 46222 and WESCO both are both above the proposed action level of ≥ 2 µg/dL for all seasons.

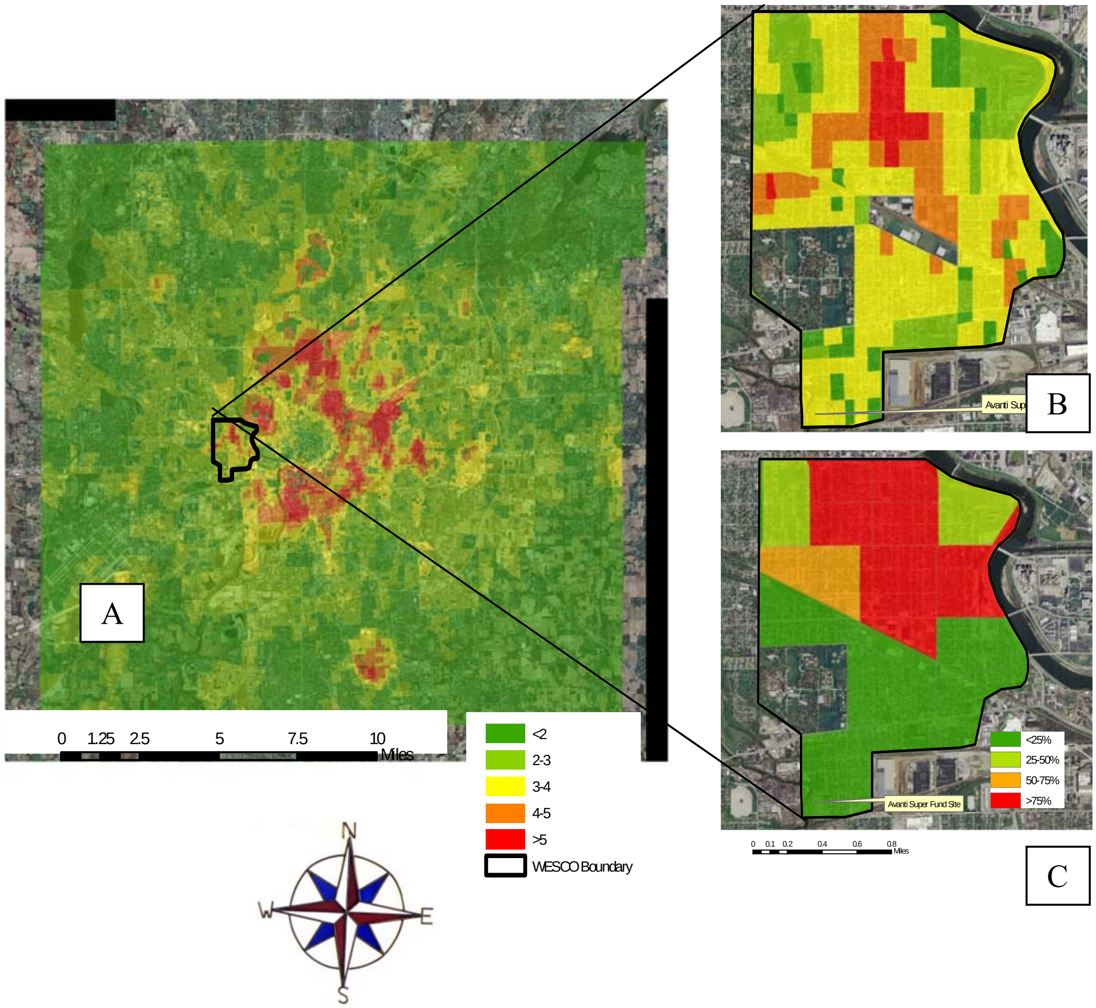

Figure 6. Average BLLs for Marion County using ordinary kriging and smoothed then averaged by US Census block for the period February 2002-December 2008 (n=12431) (6A) with the WESCO study area as a sub-set (6B). Note the urban core of higher BLLs with decreasing values as you move towards suburban areas. Area at the center of the map shows lower BLLs due to the fact that very few children live in the downtown business district. WESCO map shows higher BLLs in the north central area which is also related to the fact this area being higher overall percentage of the total population of blacks (6C).

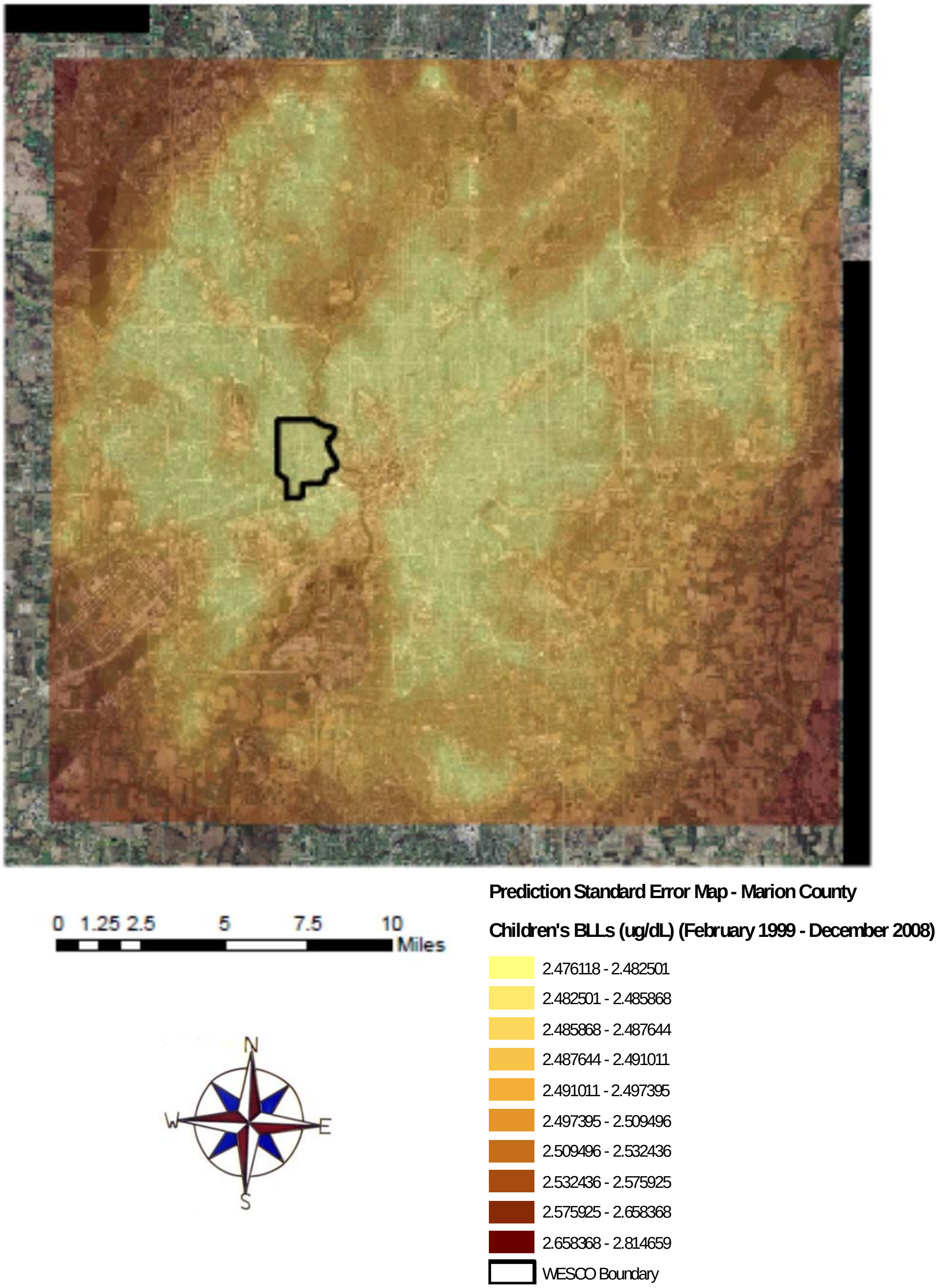

Figure 7. Kriging prediction error map used to compare against the sample standard deviation (3.36). Prediction error map shows reliable kriging results (root mean square 2.32).

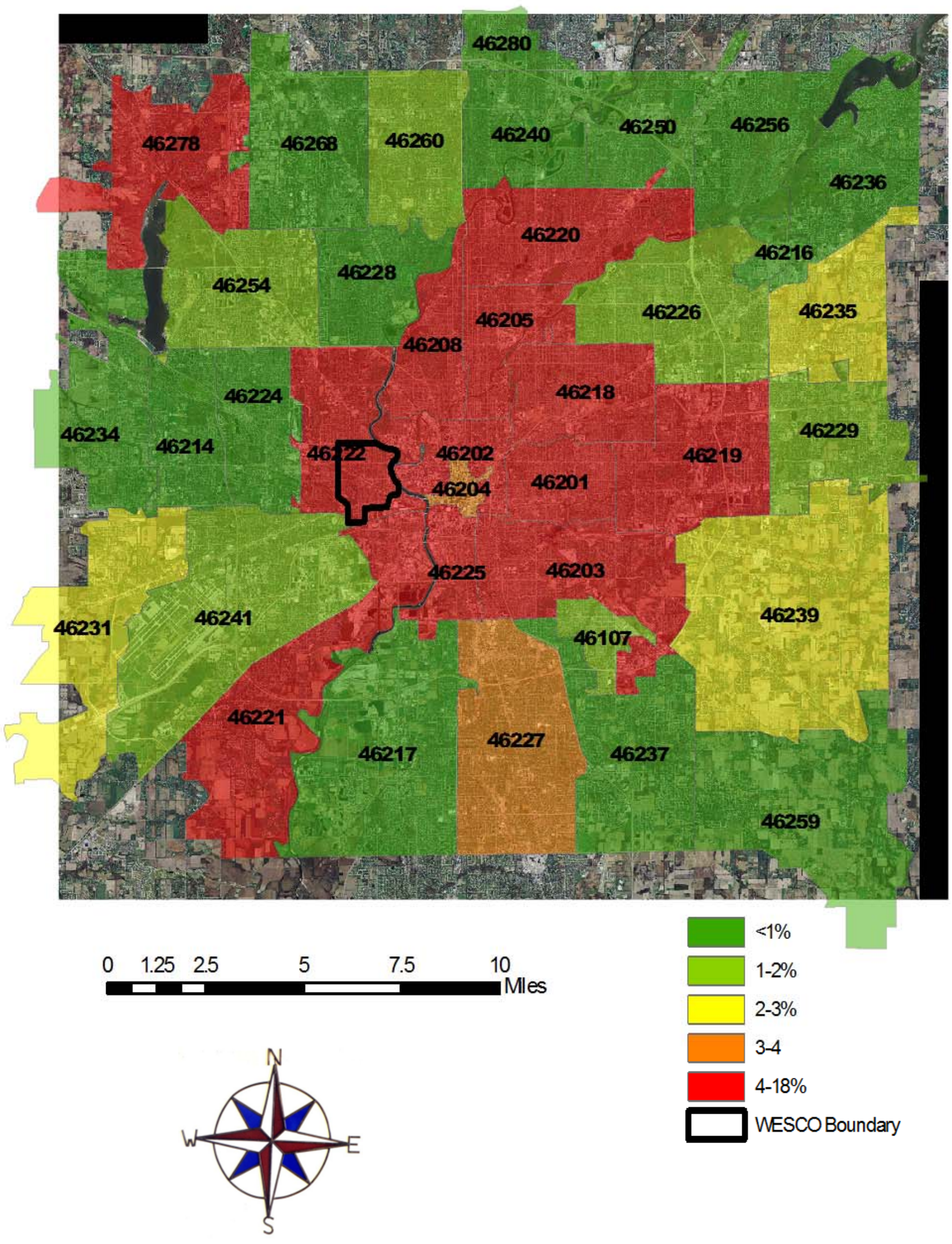

Figure 8. County breakdown of percentage of children with elevated BLLs by zip code for the period January 1999-December 2008.

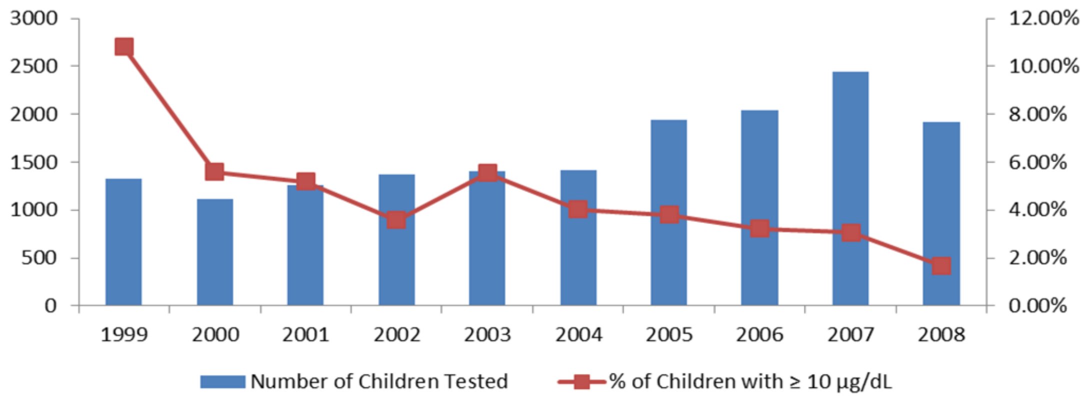

Figure 9. Number of children tested during the study period of January 1999-December 2008 with the percentage of children with elevated BLLs. Note the number of children being tested is increasing but the overall percentage of children being Pb poisoned decreasing.

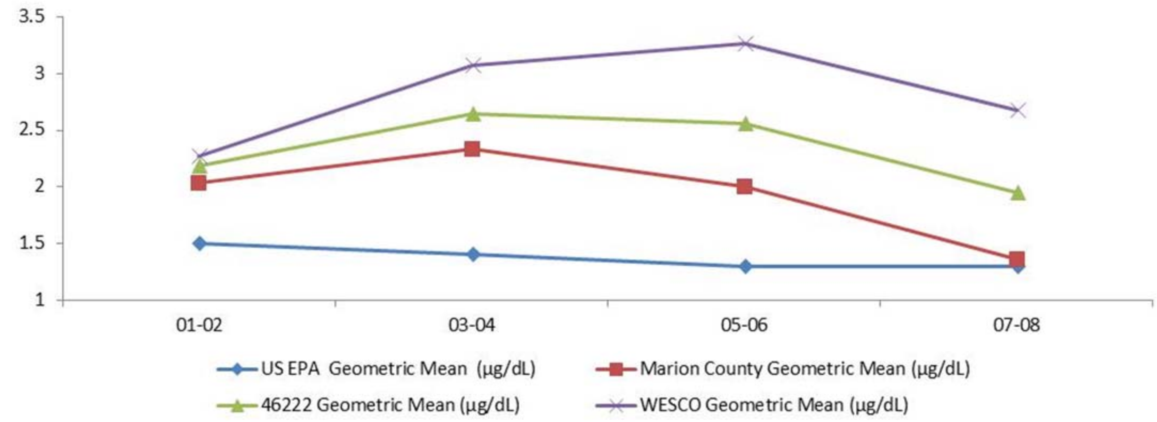

Figure 10. Geometric means for all US children as part of the National Health Nutrition Examination Survey (NHANES) as reported by the US EPA Fourth National Exposure Report (2010) and study areas of interest. Notice geometric means are higher in Marion County, Zip Code 46222 and the WESCO Neighborhood than national means.

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CURRICULUM VITAE

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EDUCATION

M.S.: Earth Sciences, Indiana University, 2011
M.P.H: Epidemiology, Indiana University, 2007
B.S: Management, Purdue University, 1994
A.A.S.: Aviation Technology, Purdue University, 1992

HONORS, AWARDS, FELLOWSHIPS

GK-12 National Science Fellowship, 2009-2011. Working directly with students grades 8-12 in an urban classroom. Applying graduate research project to the classrooms and working with to help high school students gain access to current and relevant science concepts as well as learning to communicate scientific research to a variety of audiences.

Lead IUPUI, **Outstanding Female Student Leader Award Nominee**, 2009 Part of the annual Women's History Month observance at IUPUI, the Women's History Month Committee recognizes special contributions of IUPUI female faculty, staff, and students to the campus and greater community.

Geological Society of America (GSA), Geology and Health Division, 2008. **Inaugural Outstanding Student Paper Award**. This award was received for an excellent abstract submission to a technical session at the national meeting for the GSA. Geology and Health Division recognizes the importance of the interaction between human health and geology which has been deemed a research priority by the Institute of Medicine and National Research Council.

Delta Omega Honorary Society in Public Health: Beta Zeta Chapter, 2008. This award was received for public health alumni that are actively engaged in public health work nominated and accepted by faculty members at Indiana University School of Medicine, Department of Public Health.

PROFESSIONAL EXPERIENCE

Teaching Assistant, 2007-2009. Indiana University School of Medicine, Department of Public Health. Indianapolis, Indiana. Performed duties which were instructional in nature including delivery of direct services to graduate students for Bio-Statistics and Introduction to Epidemiology courses.

Internship Preceptor, 2010-2011. Indiana University School of Medicine, Department of Public Health. Indianapolis, Indiana. Provided internship opportunities for two Master of Public Health (MPH) students focusing on lead (Pb) and mercury (Hg) contamination and their relationship to human health.

CONFERENCES AND LECTURES

Morrison-Ibrahim, D.E., Fuller, T. (December 2010). *GIS in Public Health: Overview of Geographical Information Systems (GIS) and how they can be helpful to public health work.* Lecture for the Office of Public Health Public Health Cafe, Indianapolis, IN.

Filippelli, G.M., **Morrison-Ibrahim, D.E.**, Gilbert, L., and Wiehe, S. (June 2010). *New Approaches to Identifying and Reducing Persistent Lead Exposure Pathways to Urban Populations.* Oral presentation at the Goldschmidt: Earth, Energy, and the Environment Conference, Knoxville, TN: A292.

Morrison-Ibrahim, D.E., Lin, Q., Filippelli, G.M., Buehrer, R.H. (October, 2009). *Field evaluation for testing correlation between lead concentration in household dust and soil lead values.* Poster presentation at the National Environmental Public Health Conference, Atlanta, GA.

Morrison-Ibrahim, D.E., Lin, Q., Filippelli, G.M., Buehrer, R.H. (October, 2009). *Geospatial relationships of Pb between interior dust and exterior soil: Implications for sources of Pb to urban youth.* Poster presentation at the Joint Annual Meeting of the Geological Society of America, Portland, OR.

Filippelli, G.M., **Morrison-Ibrahim, D.E.** (February 2009). *High lead levels in the blood of children in a west side Indianapolis neighborhood have spurred a study of 'legacy lead' The data will lead to strategies for improving community health, both here and in similarly afflicted inner-city communities***.** Video presentation for IU Home Pages found at http://homepages.indiana.edu/web/ page/normal/ 10098.html

Morrison-Ibrahim, D.E., Lin, Q., Filippelli, G.M., Buehrer, R.H. (October, 2008). *Correlating high blood lead levels in urban children with lead in soil using geospatial analysis and geographically referenced health data*. Poster presentation at the annual meeting of the American Public Health Association, San Diego, CA.

Morrison-Ibrahim, D.E., Lin, Q., Filippelli, G.M., Buehrer, R.H. (October, 2008). *Lead Distribution in Urban Soils: Relationship Between Lead Sources and Human Health*. Oral presentation at the Joint Annual Meeting of the Geological Society of America, Houston, TX: 282-1.

Morrison-Ibrahim, D.E., Steele, G., & O'Neil, J. (November, 2007). *Elevator related injuries among adults ages 20-64, US 1990-2002*. Poster presented at the annual meeting of the American Public Health Association, Washington, D.C.

Sweany, P., **Morrison-Ibrahim, D.E.**, & Haddix, J. (November, 2007). *Damar Services Inc. school health index assessment*. Oral presentation at the annual meeting of the American Public Health Association, Washington, D.C.