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CADMIUM EXPOSURE AND RESIDENCE-TO-ROAD PROXIMITY IN EASTERN KENTUCKY

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CADMIUM EXPOSURE AND RESIDENCE-TO-ROAD PROXIMITY IN EASTERN KENTUCKY

CAPSTONE PROJECT PAPER

This paper is submitted in partial fulfillment of the requirements for the Master of Public Health, with a concentration in Environmental Health, from the University of Kentucky

By
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Lexington, KY
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ABSTRACT

Background and Objectives

Cadmium is a carcinogenic and toxic metal. The general population can be exposed to cadmium from multiple sources. The purpose of this study is to evaluate the association of urinary cadmium and residence distance-to-road by performing landscape analyses in eastern Kentucky, a region where smoking prevalence is high, coal production has been a primary industry, and the landscape is predominantly undeveloped. Composite dust samples were also collected and analyzed for Cadmium (Cd), Manganese (Mn), and Zinc (Zn). The primary objective of this study is to ascertain if there is an association between participants with elevated accumulated cadmium exposure and residence proximity to paved roads. The secondary objective is to determine if composite dust collected on the front walkways of these residences will contain elevated concentrations of trace elements related to heavy travel, including cadmium, manganese, and zinc.

Methods

The residence distance-to-road values were determined by performing heads-up digitizing in ArcMap, a geographic information systems (GIS) software, using imagery from the Kentucky Division of Geographic Information, United States Department of Agriculture (USDA) National Agriculture Imagery Program (NAIP) 2016 2 feet resolution. The samples for urine cadmium were taken from subjects in 31 counties. A total of 178 urinary cadmium (creatinine-corrected)
values, 35 composite dust samples, and cotinine hair samples for each urinary Cd value were recorded along with the residence-to-road distance.

**Results**

After creatinine-correcting the urinary cadmium, the mean value for the 178 values was 5.89 µgCd/gCR. The correlation between non-smokers and urine Cd was -0.0004 with a p-value of 0.9970 and for smokers the correlation was -0.2635 with a p-value of 0.0224. The correlation for smokers was found to be statistically significant. SPSS was used to calculate Pearson correlation statistics for urinary Cd and residence distance-to-road. The correlation was -0.074. Of the 178 urinary Cd values, 46.1% of the subjects were found to live between 0 – 30 meters of a road.

**Conclusion**

Potential sources of exposure were analyzed but more analyses need to be performed as the urinary cadmium values and residence proximity-to-road map indicates an association between the two variables.

**INTRODUCTION**

The purpose of the Department of Defense sponsored Lung Cancer Research Initiative (LCRI) study is to identify the role of environmental carcinogens in Appalachian Kentucky (Arnold, 2014). Eastern Kentucky has extremely high incidence rates of lung cancer even when smoking was accounted for. This suggests that other factors have a role in lung cancer development in this region. There is evidence that residents in eastern Kentucky
are exposed to higher levels of trace elements than other Kentucky residents (Arnold, 2014). The hypothesis of the LCRI study is that lung cancer incidence in Appalachian Kentucky is higher than expected from smoking alone and is associated with exposure to environmental carcinogens that increase oxidative stress and DNA damage. Biological and environmental samples were collected from selected cases and controls and each participant’s residence was geocoded so latitude and longitude coordinates could be used for mapping and identification purposes (Arnold, 2014). The analysis of the urinary cadmium data provided by the LCRI showed elevated levels of concern, which lead to the evaluation of additional potential sources of cadmium in eastern Kentucky residents.

From the LCRI data, there were 180 urinary cadmium values that were \( \geq 0.60 \, \mu g/L \) of cadmium. 0.60 \( \mu g/L \) was chosen as a cut point for convenience purposes. Of these 180 values, 178 were used, as two of the values did not have Global Positioning System (GPS) coordinates, and therefore could not be mapped. After creatinine correction, biological exposures ranged from 0.25 to 50.00 \( \mu g/g \) creatinine. Once smoking status was adjusted for, the focus turned to finding another possible source of cadmium exposure. Examination of smoking status by report and quantitative hair cotinine showed no correlation with urine cadmium levels in this cohort (n=178) with elevated cadmium exposure, as shown in Table 1. (Johnson, unpublished report). Eastern Kentucky has a unique landscape in that it is largely rural, contains many valleys and steep slopes, and the primary industry has historically been coal mining. Based on these
characteristics and the potential for heavy traffic on coal-haul roads, this study evaluates whether residence proximity to the nearest road is associated with urine cadmium concentrations for a subgroup of the LCRI.

Urinary cadmium is commonly used as a biomarker to determine low to moderate chronic exposure in the general population. Healthy nonsmokers that have not been exposed to cadmium in the United States have low levels of urinary cadmium, with urinary cadmium typically increasing with age. The geometric mean for creatinine corrected urinary cadmium for 20 years and older for 2011-2012 was 0.220 µg/g of creatinine (CDC, 2015). The Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration develop regulations to protect public health, while the National Institute for Occupational Safety and Health (NIOSH), the Agency for Toxic Substances Disease Registry (ATSDR), and the American Conference of Governmental Industrial Hygienists (ACGIH publish recommendations for toxic substances like cadmium.

Cadmium is found in the environment in rocks and soil, tobacco smoke, food and water, emissions from smelting and other industries, fertilizers, biosolids, and automobile components among other sources. It is persistent in the environment and can be accumulated in organs and tissues, primarily accumulating in the kidneys (ATSDR, 2012). Inhalation of contaminated air can be a source of exposure, but this is not common unless people live near cadmium-emitting sources. Other environmental exposures primarily occur through smoking tobacco and consuming foods such as rice that absorb high
levels of cadmium from the growing medium. Excessive cadmium accumulation by both inhalation and ingestion can lead to a multitude of health conditions including lung damage, lung cancer, chronic obstructive pulmonary disease, kidney disease, bone disease, cardiovascular disease, and possible developmental effects (ATSDR, 2012).

The eastern Kentucky landscape is largely rural with sloped valleys; many communities are located in the lower part of the valleys with homes often positioned between a paved roadway and a river or stream at the valley bottom. The economy in this region has for decades been based on resource extraction, processing, and transport of mostly high quality bituminous coal from underground and surface mines to population centers in the state and beyond (Pigman, 1995). Coal trains and haul trucks are known for dust dispersal (Prakash, 2016). Rock overburden is explosively removed in both surface mining and in road construction in the region. Heavy truck traffic on narrow, hilly, and curving roadways may generate additional debris from tire and brake wear, which also contain cadmium.

The study’s purpose is to evaluate residence-to-road proximity for the cohort of participants in the Lung Cancer Research Initiative using latitude and longitude measures collected during the LCRI original study. The first proposed hypothesis is that there is an association between participants with higher accumulated cadmium exposure and residence-to-road proximity. The second hypothesis is that composite dust collected from the porches and front walkways
of these residences will contain elevated concentrations of trace elements related to heavy travel, including cadmium, manganese, and zinc.

LITERATURE REVIEW

Sources of Exposure

In Eastern Kentucky there could be multiple cadmium exposure sources besides tobacco smoke, which is one of the primary sources of cadmium. Secondhand smoke is also a source of cadmium and it has been shown that people who are around smokers have elevated urinary cadmium concentrations (Pang, 2016). The production and application of phosphate fertilizers, fossil fuel combustion, waste incineration, and nonferrous metal mining and refining are the primary anthropogenic sources of cadmium in the environment. Cadmium can be transported through air relatively easily and has the ability to travel long distances and be deposited on soil and water surfaces. Accumulation in soil is typically a result of atmospheric deposition, phosphate fertilizer application, and sewage sludge disposal. In nonsmoking adults, the primary source of cadmium exposure is through the consumption of food products that have high concentrations of cadmium, such as leafy vegetables, peanuts, soybeans, sunflower seed, shellfish, and organ meats (ATSDR, 2012).

Another potential source of exposure are automobile components that contain cadmium. Cadmium is found in brake pads and tailpipe emissions. Heavy metals, including cadmium, that are emitted from vehicles, have shown to be an issue in many urban areas (Pepescu, 2010). Cadmium is one of the many heavy
metals associated with heavy traffic roads, which lead to the hypothesis that coal-haul roads may be a potential source for cadmium exposure (Popescu, 2010). Even though roads in eastern Kentucky are not believed to have as much traffic as urban roads, roads in this region of Kentucky tend to be steep, which could cause increased braking from vehicles. Significantly elevated biological Cd concentrations could be a result of Cd plated brake parts. Cadmium is used to prevent brake corrosion and is currently used to reduce squeaking from braking. Significant wear on rotors can lead to elevated Cd releases as well. (McKenzie, 2009). Rotor age can also play a role in cadmium release, which in turn would result in higher releases of heavy metals from aged vehicles and parts (Deska, 2011). Additionally, Cd can be found in asphalt concrete road surfaces, which would support cadmium occurrence in close proximity to roads, especially if hard braking is routine. (Murphy, 2015).

**Exposure Limits**

The EPA, FDA, and OSHA have established regulations regarding cadmium release and exposures in order to protect the environmental and public health. ATSDR, ACGIH, and NIOSH also make recommendations for exposure limits to reduce potential health effects. For the purpose of this study, the recommendations and limits that are discussed include publications by ACGIH, ATSDR, and OSHA. ATSDR established the chronic-duration inhalation minimal risk level (MRL) of 0.01 µgCd/m³, which would result in a urinary cadmium level of 0.05 µg/g creatinine, assuming dietary cadmium intake of 0.3 µg/kg/day.
ACGIH has biological exposure indices (BEI) for cadmium in both blood and urine. For urinary cadmium, the BEI is 5.0 µg/g creatinine. (ATSDR, 2012). OSHA has two different regulations for creatinine-corrected urinary cadmium concentrations. The employee action level is 3 µg/g creatinine and the medical removal level is 7 µg/g creatinine. If an employee’s urinalysis result is > 3 µg/g creatinine, the employer must reexamine the employee’s occupational exposure within two weeks of receiving test results. If the employer notices deficiencies in the workplace during the reevaluation, the employer must correct the conditions within 30 days. If the biological testing results in a limit at or exceeding 7 µg/g creatinine, the employee must be medically removed from the source of exposure to cadmium. The employer has to biologically monitor the employee on a quarterly basis with semiannual medical examinations until the employee’s levels are within the acceptable action levels for medical surveillance (OSHA, 2003).

**Public Health Implications**

The main organs affected by cadmium exposure are the kidneys, lung and bones. According to the ASTDR, the kidneys can be damaged from acute and chronic exposure, but more commonly from chronic exposure. The lungs can be damaged from acute inhalation exposure as well as chronic exposure. Bone disease is considered to be secondary to cadmium’s effects on the kidney (ATSDR, 2008). Elevated or low blood pressure and hypertension have also been linked to elevated urinary cadmium concentrations. In a study done in
China, when Cd levels exceeded 2.5 μg/g creatinine, blood pressure was elevated (Wu, 2016). After controlling for age, body mass index (BMI), smoking status, and diabetes, hypertension significantly increased with increasing urinary cadmium in total subjects (Wu, 2016). Cadmium is classified as a human carcinogen by the International Agency for Research on Cancer. It is known that acute inhalation of cadmium can result in lung cancer. Low-to-moderate cadmium exposure was prospectively associated with pancreatic, lung, and total cancer mortality (Garcia-Esquinas, 2014). The Strong Heart Study (2014) evaluated cadmium exposure and cancer mortality. The results showed that after adjusting for sex, age, smoking status, and BMI, cadmium was not significantly associated with esophagus and stomach, colon and rectum, liver, breast, prostate, kidney, or lymphatic and hematopoietic cancer mortality.

RESEARCH OBJECTIVES

The primary objective of this study was to evaluate whether residence proximity to the nearest road is associated with urine cadmium concentrations for a subgroup (n=178) of the Lung Cancer Research Initiative.

The secondary objective was to determine if composite dust containing Cd, Mn, and Zn collected on the exterior of subject residences are associated with proximity to the nearest road.
METHODS

Urinary cadmium values, composite dust data for Cd, Mn, and Zn, and smoking/cotinine values were obtained from the LCRI LabKey Server. A cut point of 0.60 µg/L was used for convenience for urinary cadmium values, which allowed 180 samples to be creatinine-corrected. Two of 180 creatinine-corrected samples did not have GPS coordinates recorded, so they could not be used in this study. Once the 178 urinary cadmium values were established, the creatinine-corrected values had to be calculated. The corrected values were calculated by dividing Cd µg/L by creatinine (CR) g/L, which resulted in creatinine-corrected urinary cadmium values (µg Cd/g CR).

After the corrected urinary cadmium values were calculated, composite dust data were added to the dataset for the same study participant location. Cd, Mn, and Zn were the only heavy metals that were analyzed in this study. In the LCRI study (2014), the composite dust samples were collected on the exterior of each subject’s home, near the front doorway. Dust was swept and collected in plastic bags. These samples were then sent to the lab for analysis. There were a total of 498 composite dust samples that had a range of particulate sizes for each sample. For this study, 2 mm particle size samples were analyzed, as it covers two exposure pathways: ingestion and inhalation. A total of 101 values existed for this particle size, with 35 values matching the previously established 178 urine cadmium values. The mean values for Cd, Mn, and Zn for the 35 samples were the following: 0.28 mg/kg, 467.49 mg/kg, and 100.79 mg/kg, respectively.
Road Proximity Measurement

Once the metal concentration data were calculated and organized in Microsoft Excel, they were uploaded (tabular joined) into ESRI’s ArcGIS 10.2.2 as a comma-separated values file. Once the data file was in ArcGIS and the 178 data points were mapped based on latitude and longitude, the distance from each point (residence location) to the nearest public road was measured. For this to be done, two imagery files were served via the Kentucky Division of Geographic Information. The first file was Kentucky National Agricultural Imagery Program (NAIP) 2014 (1 meter resolution) and the second file was Kentucky NAIP 2016 (2 feet resolution). Both image services were connected into ArcGIS because they had different resolutions and the composite dust and urine data were collected in 2014. The 2014 NAIP imagery has lower resolution for what needed to be accomplished through heads-up digitizing, so the 2016 2 feet imagery was used to augment the visual quality while being temporally close. Heads-up digitizing was then used to measure the distance from the exterior front door area to the nearest public road as determined from the 2016 2 feet imagery. This distance measurement was done by using the ArcGIS measure tool. Roads that were private drives were not used for measurements. All 178 points were measured in meters. The residence proximity-to-road ranges were determined from a previously done study (Zhu, 2002). This study measured particulates at 30, 60, 90, 150, and 300 meters. Therefore, ranges used in the maps are: 0 – 30 m, 30 – 60 m, 60 – 90 m, 90 – 150 m, 150 – 300 m, and 300 – 1634 m (1634 m was the highest measurement for our dataset) (Zhu, 2002).
Once all of the data were input into the attribute table, the data could be displayed as a map. Jenks or Natural Breaks Classification was used for cadmium values in the residence distance-to-road map, Cd, Mn, and Zn composite dust values in the residence distance-to-road maps, and urinary cadmium values in the cadmium composite dust map. The Jenks Classification method helps to minimize variation within classes and is one of the most common calculations used in GIS mapping, also known as natural breaks (Brewer, 2002). Once the maps were created and formatted, they were exported from ArcGIS as PDF files.

**Statistical Analyses**

Data were added into SPSS from Microsoft Excel. A Pearson correlation coefficient was calculated for creatinine-corrected urinary cadmium values and residence distance-to-road and Cd, Mn, and Zn values and residence distance-to-road. A scatter plot (Figure 5) was also created in SPSS to show residence proximity-to-road plotted against creatinine-corrected urinary cadmium values.

**RESULTS**

A majority of the residences in this study were between 0 – 30 m from the closest road (Figure 1). Approximately 46.1% (n=82) of the 178 values fell within this distance range, while only 7.3% (n=13) of subjects live > 150 m away from the closest public road. The mean for the 178 values was 5.89 \( \mu g \) Cd/g CR. The Figure 1 legend shows two different data values; residence proximity-to-road and
creatinine-corrected Cd urinary values. As the colors lighten, the residence distance to the nearest paved public road increases, showing that the darkest color means the subject lived within 0 – 30 meters of a paved public road. The point sizes represent the urinary cadmium levels with the values ranging from 0.25 – 50.00 μg Cd/g CR. Of the 46.1% of the points where the residence-to-road proximity is within 0 – 30 m, 47.6% (n=39) of those are ≥ 3 μg Cd/g CR. The counties that have at least three values that fall within 0 – 30 m and have urinary cadmium values that exceed 3 μg Cd/g CR, include Floyd, Harlan, Letcher, Pike, Breathitt, Perry, Laurel, and Pulaski. For the 30 – 60 m range, 43.5 % (n=20) of the values exceed 3 μg Cd/g CR. 64.7% of the values within the 60 – 90 m range are ≥ 3 μg Cd/g CR. As shown in Figure 1, 83.1 % (n=148) of the subjects live within 0 – 90 m. This is noteworthy because particulate dispersion values significantly decrease as distance from roadways exceeds 90 m. (Zhu, 2002).

Urinary cadmium and residence proximity-to-road are shown in the SPSS generated scatterplot shown in Figure 5. The scatterplot is shown on a logarithmic scale to better display the data. The plot includes three reference lines representing OSHA and ACGIH medical surveillance levels. At 3 μg/g creatinine, employers should review controls in the workplace and correct any defects in the workplace that would result in elevated biological cadmium concentrations, of the 178 participants, 10.1% (n=18) have levels between 3 and 5 μg/g creatinine. 5 μg/g creatinine is the BEI published by ACGIH and is the concentration that was developed to assist in controlling health hazards. Approximately 6.7% (n=12) of participants fall within the 5 μg/g creatinine and 7
µg/g creatinine range. If an employee has a urinalysis that exceeds 7 µg/g creatinine, the employee must be medically removed from the workplace until levels are lowered. The LCRI data (n=178) contained 30.3% (n=54) of the subjects exceeding 7 µg/g creatinine. These values were included in the scatterplot to show a better understanding of the urinary cadmium concentrations from the LCRI data.

The statistics show negative correlations between smoking and high creatinine-corrected urinary Cd values, regardless of smoking status (Table 1). The correlation between smokers with high Cd is statistically significant. The Pearson correlation between creatinine-corrected urinary cadmium and residence proximity-to-road in meters shows a negative correlation (Table 2). The correlation between residence proximity-to-road and Cd composite dust collected on the exterior of the home shows a negative correlation (Table 3). Tables 4 and 5 both show weak positive correlations between dust values and residence proximity to the nearest road.

**Front Porch Composite Dust Results**

Approximately 75.0% (n=15) of the values on the map displaying Cd exterior composite dust and residence proximity-to-road within the 0 – 30 m range had values < 0.34 mg/kg (Figure 2). 57.1% (n=20) of Zn values fell within the 0 – 30 m range with 65.0% (n=13) having Zn values < 88.36 mg/kg (Figure 3). In Figure 4, 70.0% (n=14) of the manganese values are within the 0 – 30 m range that are ≥ 262.07 mg/kg.
DISCUSSION

Figure 1 shows that the majority of the data points are within 90 m of a paved public roadway. This is significant as this map shows that there is a positive correlation between residence distance-to-road and urinary cadmium values. Air particulate dispersal is greatly reduced beyond the 90 m range. (Zhu, 2002). The top coal producing counties in eastern Kentucky are the following: Pike, Perry, Harlan, Floyd, and Knott. (Ellis, 2016).

The Impacts of the Extended-Weight Coal Haul Road System paper (1995) explain how coal is transported and the impacts of the transportation system. Coal transportation primarily occurs via highway, while there is decline in the railway industry for the purpose of transporting coal. The total ton-miles for coal transported by highways have increased. The size of coal-haul trucks have steadily increased since the 1980’s and six-axle trucks dominate coal movement over Kentucky’s highways. This is important to note, as large trucks have more potential to generate, stir up, and disperse particulates due to load weights.

There were interesting findings from this study regarding the composite dust samples from the exterior front walkways. The mean values for Cd, Mn, and Zn for the 35 samples are the following: 0.28 mg/kg, 467.49 mg/kg, and 100.79 mg/kg. The generic statewide ambient background for Kentucky for Cd, Mn, and Zn are the following: 0.68 mg/kg, 1017 mg/kg, and 55 mg/kg. (DEP, 2004). The mean Zn value from the composite dust sample in the LCRI data is nearly double
than the background concentration for Kentucky. Both Cd and Mn were lower than the Kentucky ambient background concentrations.

Dietary intake of Cd is known as one of the primary sources of exposure in the general population. Leafy greens and other vegetables readily absorb and accumulate cadmium, which could result in bioaccumulation in humans. In soils that are not treated with fertilizers containing cadmium, plants are able to absorb minimal amounts heavy metals. (Smolders, 2001). In populations that consume food with low levels of cadmium where urinary cadmium excretion exceeded 2 \( \mu g/g \) creatinine, calciuria was increased by approximately 10%. (Satarug, 2004).

A study done in China showed that coal-mine brownfields can be a potential source for heavy metal exposure in that region. On the roadsides closest to coalmines, Cd, Cu, and Pb were enriched in bulk soils. Cd was shown to be a major ecological risk, while other heavy metals showed low potential for ecological risk. It was recommended that countermeasures be implemented after coal mining activities to reduce heavy metal pollution. (Li, 2017).

**CONCLUSION**

This study evaluated whether or not residence proximity to the nearest public road was associated with urinary cadmium concentrations. The map shown in Figure 1 shows that many study participants lived within 90 m of a paved road and most (n=82) of those were within 30 m of a road. The composite dust data did provide valuable information as it showed that Zn is elevated, and
Cd and Mn are fairly low compared to the background levels for the Commonwealth of Kentucky.

In the future, more analyses should be performed using the LCRI data. There are other various potential sources of exposure for heavy metals in this region, specifically Cd. Coal-haul roads should be identified and mapped, as this could potentially show whether or not elevated urinary cadmium levels are in proximity to these roads. Occupation and recreational activities should also be documented to determine if these might be potential sources of Cd exposure. Additionally, dietary intake and coal-mine brownfields could be other possible sources/explanations for these elevated urinary cadmium values in eastern Kentucky and should be examined.

**STRENGTHS AND LIMITATIONS**

This capstone project was limited to creating a GIS-based evaluation of the residence-to-road proximity for a subset of the LCRI with noteworthy accumulated cadmium exposure. This is the first GIS-based assessment of a trace element incorporating exposure data from the LCRI. The methods used have limitations including residence distance-to-road measurements, since the distances were measured by hand based on visual interpretation of imagery and GPS coordinates as opposed to an automated tool or generated calculation. The use of two or more blinded coders in the measurement process could improve precision. Composite dust samples were collected but not analyzed for all of the participants with significant cadmium included in this study, which limited the use
of those findings to generating hypotheses for additional research. Wind, elevation, slope, and age of the roads were not accounted for in this study. Because there were so few samples of composite dust samples available, these data could not be used to deduct any significant conclusions.

Participants in the LCRI with urine cadmium < 0.60 µg/L were not included in this study, but will be evaluated in future research. Future research should consider length of residence in present home and include qualitative variables available from the interview such as diet, consumptions of home-grown garden vegetables, and local subsistence hunting and fishing. Occupation and recreational activities should also be included in future research.

STATEMENT OF SUPPORT
This research was supported by the Department of Defense [Congressionally Directed Medical Research Program, U.S. Army Medical Research and Materiel Command Program] under award number: 10153006 (W81XWH-11-1-0781). Views and opinions of, and endorsements by the author(s) do not reflect those of the US Army or the Department of Defense. This research was also supported by unrestricted infrastructure funds from the UK Center for Clinical and Translational Science, NIH grant UL1TR000117.

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**ACKNOWLEDGEMENTS**

I would like to thank Dr. Johnson, Dr. Mannino, and Dr. Lee for their advice and assistance in helping me complete my capstone project.
BIOGRAPHICAL SKETCH

Ellen Flora is originally from Aiken, South Carolina. She earned her Bachelor of Science degree in Natural Resources and Environmental Science from the University of Kentucky in 2013. Currently, she is a Master of Public Health candidate in Environmental Health at the University of Kentucky. During her time at UK, she was a co-op at Toyota Motor Manufacturing Kentucky and is currently an Industrial Hygienist at Savannah River Nuclear Solutions.
APPENDIX 1. TABLES AND FIGURES

Maps throughout this paper were created using ArcGIS® software by Esri. ArcGIS® and ArcMap™ are the intellectual property of Esri and are used herein under license. Copyright © Esri. All rights reserved. For more information about Esri® software, please visit www.esri.com.

Table 1. Correlation statistics: Smoking status and urinary cadmium values. (Johnson, unpublished data).

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Table 2. Correlation statistics: Urinary cadmium values and residence distance to road.

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Table 3. Correlation Statistics: Cd composite dust values and residence distance to road.

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|        |                             |                           |                         |
| Dist   |                             | -0.077                    | 1                       |
| Sig. (2-tailed) Dist | 35                      | 35                        |                         |
Table 4. Correlation Statistics: Zinc composite dust values and residence distance to road.

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Table 5. Correlation Statistics: Manganese composite dust values and residence distance to road.

<table>
<thead>
<tr>
<th></th>
<th>MnSoil</th>
<th>Dist</th>
</tr>
</thead>
<tbody>
<tr>
<td>MnSoil</td>
<td>Pearson Correlation</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>35</td>
</tr>
<tr>
<td>Dist</td>
<td>Pearson Correlation</td>
<td>.186</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.285</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>35</td>
</tr>
</tbody>
</table>
Figure 1. Map displaying creatinine-corrected urinary cadmium values with relation to residence proximity to public road.
Figure 2. Map displaying Cd composite dust values and residence proximity to public road.
Figure 3. Map displaying Zn composite dust values and residence proximity to public road.
Figure 4. Map displaying Mn composite dust values and residence proximity to public road.

Manganese Exterior Composite Dust Values and Residence Distance to Road

Legend

Distance to Road & Mn mg/kg

0-30 m 57.1% n=20

70.86 - 262.06
262.07 - 539.52
539.53 - 922.68
922.69 - 1229.45

30-60 m 20.0% n=7

70.86 - 262.06
262.07 - 539.52
539.53 - 922.68
922.69 - 1229.45

60-90 m 8.6% n=3

70.86 - 262.06
262.07 - 539.52
539.53 - 922.68
922.69 - 1229.45

90-150 m 8.6% n=3

70.86 - 262.06
262.07 - 539.52
539.53 - 922.68
922.69 - 1229.45

150-300 m 5.7% n=2

70.86 - 262.06
262.07 - 539.52
539.53 - 922.68
922.69 - 1229.45

Distance to road data derived from head-up digitizing. See references for more information. Map created by Ellen Price, 2011.
Figure 5. Scatterplot displaying creatinine-corrected urinary cadmium values plotted against residence proximity to public road.