Volume 12

Article 10

2023

The Influence of Vehicular Traffic and Land Use Typology on the Spatial Patterns and Concentrations of Soil Lead (Pb) in the Uptown Community Area of Chicago

Andreas 'Dre' Harris
DePaul University, aharr144@depaul.edu

The Influence of Vehicular Traffic and Land Use Typology on the Spatial Patterns and Concentrations of Soil Lead (Pb) in the Uptown Community Area of Chicago

Acknowledgements

I would like to thank the many people who made this project possible. Dr. Montgomery, my research advisor, for his invaluable guidance and advice; Hanna Petroski and Emma Sznewajs for their assistance in the laboratory; Kennedy Schuh, for her support and encouragement; Dr. Montgomery's HON 225 SQ lab class for their help during sample collection; and DePaul's College of Science and Health's Undergraduate Summer Research Program for financial support.

The Influence of Vehicular Traffic and Land Use Typology on the Spatial Patterns and Concentrations of Soil Lead (Pb) in the Uptown Community Area of Chicago

Andreas 'Dre' Harris*

Department of Environmental Science and Studies

James Montgomery, Ph.D.; Faculty Advisor

Department of Environmental Science and Studies

ABSTRACT Lead (Pb) is a harmful element whose presence threatens the well-being of living organisms and their environments. There are higher concentrations and an increased risk of Pb exposure in areas that provide fewer natural pathways for Pb to accumulate into. In urban areas, the soil is one of the most common and available environmental sinks for Pb accumulation. This study examines the total soil Pb concentrations in relation to land-use types and average daily traffic volumes (cars/day) in each census tract in the Uptown Community Area of Chicago. This study provides insight into how land use and traffic volume may affect total soil Pb. This study hypothesizes that total soil Pb concentrations will be higher in areas with more non-residential land use, including commercial and industrial land use, and that total soil Pb concentrations will be higher in areas with higher average daily traffic volumes.

Soil samples were collected with the help of DePaul University citizen scientists from five randomly generated locations in the parkways of each census tract in the Uptown Community Area on the North side of Chicago. Soil Pb concentrations of each sample were determined using EPA Method 3050B acid-digestion method.

The average daily traffic volumes (obtained from the City of Chicago and the Illinois Department of Transportation), the percentage of commercial and industrial land use (obtained from the Metropolitan Agency for Planning), and the average soil Pb concentration by census tract were mapped using ArcGIS Pro. There was no statistically significant difference in mean soil Pb concentrations between census tracts. There was no statistically significant effect of average daily traffic volumes or percentage of commercial and industrial land use on soil Pb concentration. A correlation test indicated that there is no significant correlation between the average daily traffic volumes and soil Pb concentration between census tracts but was suggestive of a moderate positive correlation between these variables. A correlation test between the percentage of commercial and industrial land use and soil Pb concentrations did not produce a statistically significant correlation but was suggestive of a moderate positive correlation between these variables.

* *aharr144@depaul.edu*

Research Completed in Summer 2022

INTRODUCTION

Lead (Pb) is a naturally occurring metal in Earth's crust and an environmental toxin with long-lasting and widely distributed concentrations and health effects. The health effects of low-level lead exposure include neurological, immune, renal, and reproductive damage. Children with elevated blood lead levels experience neurological effects such as behavioral and intellectual deficiencies (U.S. Department of Health and Human Services, 2012). A primary pathway of Pb into the body is through the inhalation of Pb-contaminated dust and the ingestion of Pb-contaminated soil, often through hand-to-mouth interactions (Mielke & Reagan, 1998).

Pb has historically been used for many applications, including as an additive to gasoline, as a main ingredient in lead-based paints, and as a construction material for pipes. Pb quickly became strongly regulated, and often banned, in many parts of the world due to the negative human health effects it presents. The U.S. has taken action to address the risk of Pb exposure through many laws and regulations on Pb (U.S. EPA, 2021), resulting in an observed decrease in child blood lead levels of 93.6% since U.S. regulations of Pb began in 1970 (Dingnam et al., 2019). Despite this, Pb still poses a significant threat to public health. Pb is resistant to rapid environmental degradation, especially when it accumulates in soil, and this allows it to accumulate over time.

Urban landscapes offer a unique environment for Pb accumulation and exposure. Most urban landscapes have long since covered up their respective native landscapes and replaced them with cement or other impervious materials. These materials limit the amount of available environmental sinks for Pb accumulation. Soil is one of the few available sinks commonly in urban areas. Urban soils are often highly disturbed by development and landscaping projects (Burgos Hernández et al., 2019), and they often have higher Pb concentrations than rural areas due to a heavy industrial footprint.

Past research has highlighted many different anthropogenic factors that can increase soil Pb concentrations. Laidlaw et al. (2015) explored the relationship between Pb emissions from the use of leaded gasoline and the higher rates of disease caused by Pb exposure. Even though the sale of leaded gasoline has been highly regulated in the U.S. since 1996, multiple metals (including Pb) from the combustion of leaded gasoline can still be found in the soil today (Wang et al., 2022). Eqani et al. (2016) examined differences in Pb concentrations between industrial, urban, or rural land-use types. Their results indicate that industrial and urban areas had higher concentrations of Pb.

Research and education are necessary to prevent exposure to Pb and its harmful effects. Pb threatens many important aspects of local community life and further jeopardizes food security for those reliant on gardening (Clark et al., 2006). The risk of Pb exposure is a known and widespread health concern in Chicago, with total soil Pb concentrations being 11 times greater than natural concentration levels (220 ppm Pb in Chicago, Watson et al., 2022).

This study is a continuation of Dr. James Montgomery's '*What's in Your Soil?'* (WIYS) project. This project aims to measure and map different soil health indicators, including Pb, in urban soils in Chicago community areas. The Uptown community area of Chicago was selected as this paper's study site to continue WIYS in Northside community areas. This study aims to provide insight into the influence of traffic volumes (a measure of cars per day) and land use typology, with a specific interest in commercial and industrial land use on the soil Pb concentrations in parkways located in the Uptown Community Area of Chicago.

Hypotheses

H_o^1: The average soil Pb concentrations are not higher in areas with more commercial and industrial land use.

H_a^1: The average soil Pb concentrations are higher in areas with more commercial and industrial land use.

H_o^2: The average soil Pb concentrations are not higher in areas with larger average daily traffic volumes.

H_a^2: The average soil Pb concentrations are higher in areas with larger average daily traffic volumes.

METHODS

Sample Collection and Analysis

Soil samples were collected at five randomly generated parkway locations in each Uptown census tract with the help of citizen scientists from DePaul University (Figure 1). The total Pb concentration (ppm) for each sample was determined following EPA Method 3050B, an acid digestion of a soil sample followed by a flame atomic absorption spectrometry analysis (U.S. EPA, 1996). The sampling locations were visualized using ArcGIS Pro (Esri Inc., 2022), and the average soil Pb concentrations in each census tract were computed.

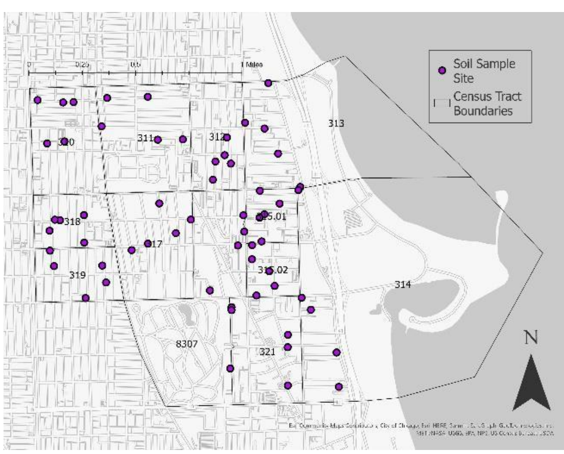

Figure 1. Uptown Soil Sample Site Locations.

Data Preparation and Analysis

A land use dataset was obtained from the *Land Use Inventory for Northeast Illinois* (Metropolitan Agency for Planning, 2015). This data set was used to determine the percentage of each Uptown census tract's total area dedicated to each land use type. The percentage of industrial and commercial land use types was summed to characterize each census tract.

Two traffic volume data sets were obtained from the City of Chicago (Chicago Data Portal, 2011) and the Illinois Department of Transportation (Illinois Department of Transportation, 2018). These data sets were combined to increase the number of data points contained within each census tract. These data sets provided a count of vehicles that pass in both directions at given points on streets and intersections for 24 hours. An overall characterization of each census tract was fit by taking the average of each daily traffic volume data point present in the census tract and dividing it by the census tract area in acres.

All statistical tests were run in R Software (R Core Team, 2021), with all tests using an α-value of 0.05. The normality of average soil Pb, daily traffic volume, and land use typology was determined using the Shapiro-Wilk test. A one-way analysis of variance (ANOVA) was used to determine if there is a statistically significant difference between all soil Pb concentrations by census tract. A two-way ANOVA was used to determine if there is a statistically significant effect of average daily traffic volumes and percentage of commercial and industrial land use on average soil Pb concentration by census tract. Pearson's r was used to evaluate any relationships between the percentage of commercial and industrial land use and the average daily traffic volumes and average soil Pb concentration.

RESULTS

Data Analysis and Generated Maps

The percentage of commercial and industrial land use (Figure 2), average daily traffic volumes (Figure 3), and average soil Pb concentration (Figure 4) were mapped by census tract. Data by census tract can be found in Table 1.

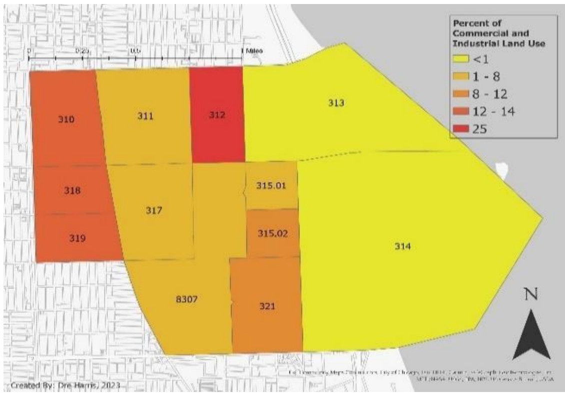

Figure 2. Percentage of commercial and industrial land use by census tract.

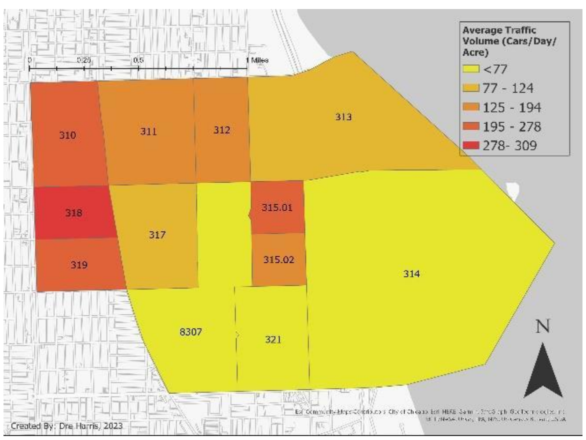

Figure 3. Average daily traffic volume (cars/day/acre) by census tract.

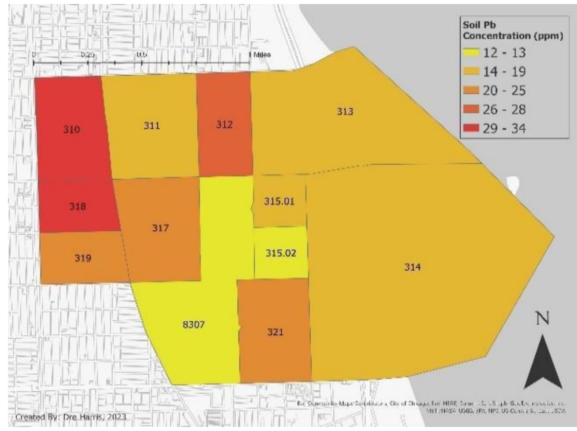

Figure 4. Average soil Pb concentration (ppm) by census tract.

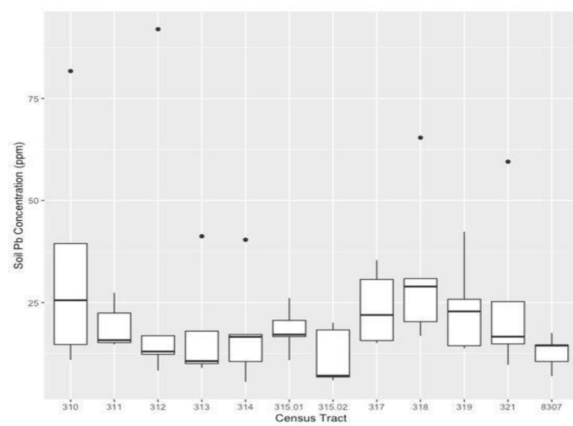

Figure 5. Box plot of soil Pb concentration (ppm) by census tract. The quartile distribution and means of soil Pb concentrations are shown as a white box with whiskers. Outliers are black points laying outside a box.

Table 1. Data summarized by census tract.

Census Tract	310	311	312	313	314	315.01	315.02	317	318	319	321	8307
Average Soil Pb Concentration (ppm)	34.48	19.11	28.50	17.78	18.05	18.29	11.63	23.75	32.47	23.83	25.20	12.83
Percentage of Commercial and Industrial Land Use (%)	12.69	8.02	24.53	0.23	0.46	4.86	11.78	6.59	13.90	13.49	10.73	6.77
Average Daily Traffic Volume (cars/day/acre)	249	153	194	108	56	278	152	124	309	262	77	69

Statistical Tests

The Shapiro-Wilk test for normality revealed that the average soil Pb concentrations ($p = 0.628$), the percentage of commercial and industrial land use ($p = 0.445$), and the average daily traffic volume ($p = 0.358$) were all normally distributed. The one-way ANOVA of soil Pb concentrations revealed that there is no statistically significant difference in soil Pb concentrations between census tracts ($p = 0.204$). The two-way ANOVA revealed that there was not a statistically significant interaction between average daily traffic volume and soil Pb concentration ($p = 0.214$) and that there was no statistically significant interaction between the percentage of commercial and industrial land use and soil Pb concentration ($p = 0.061$).

Pearson's r indicated no significant correlation exists between average daily traffic volumes and soil Pb concentrations ($r(10) = 0.555$, $p = 0.0609$). The second test indicated that there is not a significant correlation between the percentage of commercial and industrial land use and soil Pb concentrations ($r(10) = 0.546$, $p = 0.0663$).

DISCUSSION

The total soil Pb concentration of each sample collected was well below the mean soil Pb concentration in Chicago (395 ppm: Cannon & Horton, 2009). All total soil Pb concentrations were below the EPA-defined hazardous soil Pb concentration of 400 ppm in children's play areas (U.S. EPA, 2021). This suggests that there is no immediate concern for residents who desire to grow vegetables or children who wish to play in these soils. However, soil Pb concentrations are often affected by local and site-specific environmental factors, including the presence of lead paint chips or the disproportionate accumulation of Pb derived from atmospheric deposition of Pb droplets during the combustion of leaded fuel. This study did not account for site-specific sources of variability in soil Pb concentrations; this warrants a study of its own.

There was no statistically significant difference in soil Pb concentrations by census tract. The range of average soil Pb concentrations was from 12 to 34 ppm (Figure 5). While there were a few statistical outliers, as shown in Figure 5, this range is quite small especially when considering other areas of Chicago with much higher average soil Pb concentrations. For example, the average total soil Pb concentrations in the West Elsdon and Lakeview community areas are 222 ppm and 320 ppm, respectively (Garcia, 2022).

Both correlation tests did not indicate a significant correlation between the selected variables and average soil Pb concentrations. The average daily traffic count datasets did not consider the large volume of traffic along DuSable Lake Shore Drive (a major highway along the lakefront) because no soil samples were collected from census tracts straddling DLSD. These tracts are in Montrose Beach and managed by the Chicago Park District. Collecting soil samples from these tracts would have required a permit from the Park District. In addition, five randomly located sample sites in these tracts were insufficient to adequately determine the effects of the heavy traffic in this area on soil Pb concentrations. Therefore, we must accept our null hypothesis, that the average soil Pb concentrations are not higher in areas with larger average daily traffic volumes.

There is no statistically significant difference or correlation between the percentage of commercial and industrial land use and average soil Pb concentration by census tract. We must accept our null hypothesis that the average soil Pb concentrations are not higher in areas with more commercial and industrial land use. Uptown is not known to have had a heavy industrial footprint, and specifically, it had no major Pb-polluting industries. The obtained p-value was only slightly larger than the chosen α-value. This suggests a relationship between the percentage of commercial and industrial land use and average soil Pb concentration, though this requires further investigation. For example, an assessment of Chicago community areas that have an extensive history of Pb pollution, such as Garfield Park and Bronzeville, and their respective land use change since Pb laws and regulations were enacted, would allow for an interesting exploration of the long-lasting effects of Pb, populations most at risk to Pb exposure, and the effects of land use change on soil Pb concentrations.

ACKNOWLEDGEMENTS

I would like to thank the many people who made this project possible. Dr. Montgomery, my research advisor, for his invaluable guidance and advice; Hanna Petroski and Emma Sznewajs for their assistance in the laboratory; Kennedy Schuh, for her support and encouragement; Dr. Montgomery's HON 225 SQ lab class for their help during sample collection; and DePaul's College of Science and Health's Undergraduate Summer Research Program for financial support.

REFERENCES

Burgos Hernández, Tania & Slater, Brian & Shaffer, Jared. (2019). *Characterizing Minimally Disturbed Soils in a Highly Disturbed Urban Environment*, d o i : 10.2134/age2019.07.0053.

Cannon, W., & Horton, J. (2009). Soil geochemical signature of urbanization and industrialization - Chicago, Illinois, USA. *Applied Geochemistry*, *24*(8), 1590-1601. doi: 10.1016/j.apgeochem.2009.04.023

Chicago Data Portal. *Average Daily Traffic Counts.* 2011. The city of Chicago. https://data.cityofchicago.org/Transportation/Average-Daily-Traffic-Counts/pfsx-4n4m

Clark, H. F., Brabander, D. J., & Erdil, R. M. (2006). Sources, Sinks, and Exposure Pathways of Lead in Urban Garden Soil. *Journal of Environmental Quality, 35*(6), 2066–2074. https://doi-org.ezproxy.depaul.edu/10.2134/jeq2005.0464

Dignam, T., Kaufmann, R. B., LeStourgeon, L., & Brown, M. J. (2019). Control of Lead Sources in the United States, 1970-2017: Public Health Progress and Current Challenges to Eliminating Lead Exposure. *Journal of Public Health Management and Practice*: S13–S22. https://doi.org/10.1097/PHH.0000000000000889

Eqani, S. A., Khalid, R., Bostan, N., Saqib, Z., Mohmand, J., Rehan, M., Ali, N., Katsoyiannis, I. A., & Shen, H. (2016). Human lead (Pb) exposure via dust from different land-use settings of Pakistan: A case study from two urban mountainous cities. *Chemosphere, 155*, 259–265. https://doi.org/10.1016/j.chemosphere.2016.04.036

Esri Inc. (2022). *ArcGIS Pro* (Version 3.0.3). Esri Inc. https://www.esri.com/en-us/arcgis/products/arcgis-pro/overview.

Garcia, Jennifer (2022) What's in Your Soil? A Comparative Assessment of Total Lead in Soils in Southwest Side and North Side Chicago Communities, *DePaul Discoveries, 11*(1), 1-8. https://via.library.depaul.edu/depaul-disc/vol11/iss1/6

Illinois Department of Transportation (2018). *Traffic Count Database System*. Traffic count database system (TCDS). https://idot.public.ms2soft.com/tcds/tsearch.asp?loc=Idot&mod=

Laidlaw, M. A., Rowe, D. B., Ball, A. S., & Mielke, H. W. (2015). A Temporal Association between Accumulated Petrol (Gasoline) Lead Emissions and Motor Neuron Disease in Australia. *International Journal of Environmental Research and Public Health, 12*(12), 16124–16135. https://doi.org/10.3390/ijerph121215047

Metropolitan Agency for Planning. 2015. *Land Use Inventory for Northeast Illinois, 2015.* Version 1. Chicago Metropolitan Agency for Planning. https://datahub.cmap.illinois.gov/dataset/land-use-inventory-for-northeast-illinois-2015.

Mielke, H. W., & Reagan, P. L. (1998). Soil is an important pathway of human lead exposure. *Environmental health perspectives*, *106 Suppl 1*(Suppl 1), 217–229. https://doi.org/10.1289/ehp.98106s1217

R Core Team (2021). *R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria*. https://www.R-project.org/.

U.S. Department of Health and Human Services. (2012). *2012 HHS Environmental Justice Strategy and Implementation Plan. U.S. Department of Health and Human Services*. https://www.hhs.gov/sites/default/files/environmentaljustice/strategy.pdf

U.S. EPA. 1996. *Method 3050B: Acid Digestion of Sediments, Sludges, and Soils*. Revision 2. Washington

U.S. EPA. (2021). *Lead Regulations*. EPA. https://www.epa.gov/lead/lead-regulations

Wang, X., Birch, G. F., & Liu, E. (2022). Traffic emission dominates the spatial variations of metal contamination and ecological-health risks in urban park soil. *Chemosphere*, *297*, 134155. https://doi.org/10.1016/j.chemosphere.2022.134155

Watson, G. P., Martin, N. F., Grant, Z. B., Batka, S. C., & Margenot, A. J. (2022). Soil lead distribution in Chicago, USA. *Geoderma Regional*, *28*. https://doi.org/10.1016/j.geodrs.2021.e00480