THE OCCURRENCE OF LEAD IN SOIL AND VEGETABLES AT A COMMUNITY GARDEN IN OMAHA, NEBRASKA

Jodi Lynn Sangster
Graduate Student, Department of Civil Engineering
University of Nebraska-Lincoln
jsangster@unomaha.edu

Andrew Nelson
Senior, Department of Civil Engineering
University of Nebraska-Lincoln
acnelson@unomaha.edu

Shannon L. Bartelt-Hunt
Assistant Professor, Department of Civil Engineering
University of Nebraska-Lincoln
sbartelt@unomaha.edu

Abstract – Lead is a persistent and ubiquitous pollutant in urban environments and is of significant importance to public health. One potential pathway for exposure to lead can be consumption of produce grown in lead-contaminated soil. This may be of increasing concern as urban community gardens experience a resurgence in popularity and demand for locally grown produce increases. For this project, soil and vegetable samples were collected from a community garden with known soil lead contamination. Soil and vegetable samples were evaluated for total lead content using atomic absorption spectroscopy. The concentrations of lead measured in soil ranged from 4 to 574 mg/kg, with an average lead concentration in the growing beds of 128.4 mg/kg and in the OmaGro compost of 31.5 mg/kg. Additionally, lead was present in vegetable samples at or below 16.25 mg/kg.

Index Terms – Community gardens, lead, soil, vegetables.

INTRODUCTION

Lead is a persistent and ubiquitous soil pollutant in urban environments and is of significant public health importance as it acts as a neurotoxin, particularly to children. Elevated lead concentrations in soil are primarily due to the use of lead-based paint, which was used in the majority of residential structures prior to 1978, and from emissions from combustion of leaded gasoline. Other sources of lead contamination include industrial emissions, waste incineration, and pesticide application. Average lead concentrations in agricultural soils range from less than 1 mg/kg to 135 mg/kg. In urban environments, lead soil concentrations can be 1000 mg/kg on average.

One potential pathway for exposure can be consumption of produce grown in lead-contaminated soil, although there is relatively little information available about what types of produce accumulate more lead relative to others and the relationship between soil lead concentrations and concentration of lead in produce. There is some evidence that various types
of plants exhibit differential uptake of lead. Agbenin et al. found higher concentrations of lead in lettuce (3.78 to 15.6 mg/kg on a dry weight basis) compared with the concentration found in amaranthus (1.30 to 3.54 mg/kg on a dry weight basis) planted in the same field. Amaranthus is commonly consumed as both a leaf vegetable and as a cereal. In another study, reported lead concentrations in parsley and pumpkins were lower than concentrations reported for other vegetables including cabbages, carrots, cauliflower, cucumbers, eggplants, green peppers, spinach, sweet potatoes and tomatoes.

The purpose of this project was to sample soil and vegetables obtained from a community garden located within an urban area with known soil lead contamination. The goals of this project were to generate a map of soil lead concentrations and to evaluate if vegetable lead concentrations are related to soil lead levels while giving undergraduate students an opportunity to research a relevant environmental issue while helping the community. This project was conducted as part of an environmental engineering laboratory course at the University of Nebraska. The course instructor approached the community garden about this project in order to provide a hands-on service learning experience for students. The intended beneficiaries of the project were the community garden as well as the larger community. The community garden benefited as the information provided allowed them to make management decisions to minimize the amount of lead in soil and vegetables. The larger community was a second beneficiary as they were also provided with information about the amount of lead detected in soil and vegetables.

**METHODS AND MATERIALS**

**Study location**
This study was conducted at City Sprouts community garden located at 4002 Seward St. in Omaha, Nebraska, NE, USA. The garden is located within the boundaries of the Omaha Lead Superfund site, which consists of a 27 square mile area in Eastern Omaha with elevated lead concentrations in soil. This area encompasses 15,000 residential properties and was placed on the National Priorities List in 2003.

**Soil Collection and Preparation**
In November 2010, soil was collected from garden beds approximately 6 to 12 cm below the surface. Four replicate samples were collected from each growing bed tested. Three samples were used in the lead extraction procedure. These were approximately 50 g in size and were sieved to remove particles bigger than 2 mm. This was done to remove any additional organic material such as leaves and roots from the soil that might interfere with the extraction procedure. The three sieved soil samples were placed in a drying oven for 24 hours before extracting for lead. The fourth sample (approximately 200 g) was collected intact for additional analysis including soil pH and electroconductivity.

**Vegetable Collection and Preparation**
Vegetables, including tomato, eggplant, okra, onion, arugula, and leafy greens, were collected at the end of the growing season, approximately 1 month before soil collection occurred. All vegetables were stored at -20°C until processing. Upon thawing, samples, with exception of the leafy greens and arugula, were washed. Leafy greens and arugula were too fragile to allow for
proper washing. Vegetable samples were finely chopped, weighed and placed in a drying oven for 12 hours. The final dry weight was recorded.

**Total Lead Extraction Procedure**

Each lab group was responsible for extracting total lead from 1 vegetable sample, three soil samples, and a quality control soil sample comprised of clean soil spiked with a known concentration of lead. All samples were extracted using the same procedure. The procedure used was a nitric acid/ concentrated hydrogen peroxide process. Briefly, approximately 1 g of sample was boiled in concentrated nitric acid to dissolve organic material and lead. This was allowed to cool before the addition of hydrogen peroxide. The remaining extract was concentrated to approximately 25mL of solution. Soil samples were centrifuged to remove any remaining particulates. Vegetable samples were filtered using a glass fiber filter to remove particulates.

**Measurement of Total Lead Content**

The liquid extracts were analyzed for total lead using atomic absorption spectroscopy (AAS). This process involves igniting the liquid extract while exposing it to a specific wavelength of light. The amount of light that makes it through the sample can be recorded and compared to solutions containing known concentrations of lead. For lead, there are several wavelengths of light that can be used. A wavelength of 283.3 nm was used for the soil extracts. This was chosen based on estimated soil lead concentrations found in the area. However, the vegetables contained significantly less lead than the sediments. To allow for more sensitive measurements of lead, it was necessary to use 217 nm for these samples.

**Class Organization**

The laboratory class was comprised of 45 students. The students were divided into two laboratory sections which each met for a three hour period 1 day per week. Between the two laboratory sections, there were a total of 15 laboratory groups with three students in each group. Preliminary information about this project was presented to students during a corresponding lecture course. This laboratory module consisted of three laboratory meetings with an additional day scheduled for oral presentations. During the first meeting, students went to the community gardens to collect soil from assigned areas. During this visit, the students were also able to observe the community in which the garden is located and interact with community garden staff members and volunteers. After returning to the lab, the students extracted the lead from soil and vegetables during the second meeting and analyzed samples using AAS during the third meeting time. Students were then able to prepare a presentation based on the procedures and data. This was disseminated to fellow classmates and board members from the community garden.

This laboratory module was developed with minimal costs using readily available supplies. Beakers, watch glasses, boiling beads, heaters, and AAS were already available in the lab. Nitric acid and hydrogen peroxide were purchased from Fisher Scientific. Cost of consumable materials and supplies was approximately $2.00 per sample.

**RESULTS AND DISCUSSION**

The results of analysis for total lead content and their general location within the garden can be seen in Figure 1. Recovery of lead from positive controls (clean soil spiked with a known
quantity of lead) was 82% on average (recoveries ranged from 59-96%). The concentrations of lead measured in soil ranged from 4 to 574 mg/kg. With a few exceptions, most of the soil samples had lead concentrations below the action level set by the United States Environmental Protection Agency (USEPA) for Omaha, NE at 400 mg/kg. There was some variability in lead concentrations in soil samples obtained from a single bed. The most variability was observed in a growing bed where the three soil samples had lead concentrations of 28, 226, and 574 mg/kg. Some of this variability may be due to wind-blown soil contamination from an off-site location. The growing bed samples had been previously amended with OmaGro compost. Samples obtained directly from the compost pile located on-site had lead concentrations ranging from 7 to 73 mg/kg. Since the concentrations measured in the beds were higher than 100 mg/kg at some locations, this may indicate that re-contamination of the beds has occurred. Alternatively, it could be that lead levels in soil prior to compost amendment were extremely high, and additional compost amendment could be used to lower concentrations in these areas.
FIGURE 1

Map of lead concentrations in mg/kg of soil and vegetables at City Sprout's Community Garden Decatur Street plot in Omaha.

TABLE 1

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>Control 1</th>
<th>Control 2</th>
<th>Control 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomatoes</td>
<td>12.0</td>
<td>15.0</td>
<td>18.0</td>
</tr>
<tr>
<td>Onion</td>
<td>21.0</td>
<td>24.0</td>
<td>27.0</td>
</tr>
<tr>
<td>Lettuce</td>
<td>11.0</td>
<td>14.0</td>
<td>17.0</td>
</tr>
</tbody>
</table>

*Figures are not to scale.*
Table 1 lists the concentration of lead found in various vegetables grown at this site. Lead concentrations of 0.35 and 3.5 mg/kg were measured in tomato samples; 3.7 mg/kg was measured in okra; 1.8 mg/kg was measured in eggplant; 0.25 mg/kg was measured in onion; and 16 mg/kg measured in leafy greens. The high lead levels found in the leafy greens may be at least partially explained by the lack of washing before testing as soil particles sticking to the greens may be contributing lead. The lead concentrations observed in tomatoes grown in soil with concentrations less than 100 mg/kg were lower than those measured in tomatoes grown in soil with a lead concentration of greater than 100 mg/kg. There is not currently any regulatory limit on lead in food; however, a limit of 0.5 mg/kg has been established by the U.S. Food and Drug Administration (FDA) for lead in glazed dinnerware. Based on this limit, the samples of leafy greens, eggplant, okra, and one of the tomato samples would be over this limit. Based on the limited number of samples tested, it is difficult to draw conclusions based on this data. Additional testing of vegetables, including more replicate samples would be appropriate.

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>n</th>
<th>Lead Content (mg/kg per wet weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato (grow in soil with &lt; 100mg/kg lead)</td>
<td>2</td>
<td>0.355 ± 0.03</td>
</tr>
<tr>
<td>Tomato (grow in soil with &gt; 100mg/kg lead)</td>
<td>3</td>
<td>3.52 ± 0.04</td>
</tr>
<tr>
<td>Okra</td>
<td>2</td>
<td>3.7 ± 1.5</td>
</tr>
<tr>
<td>Eggplant</td>
<td>1</td>
<td>1.83</td>
</tr>
<tr>
<td>Onion</td>
<td>1</td>
<td>0.26</td>
</tr>
<tr>
<td>Leafy Greens</td>
<td>2</td>
<td>16.25 ± 10.1</td>
</tr>
</tbody>
</table>

In conclusion, based on the results of this testing, the concentration of lead across the garden is generally below the action limit of 400 mg/kg set by the US EPA for Omaha, NE. Test results from vegetables indicate that some lead is present in food; however, additional testing is warranted as a limited number of samples were evaluated.
**Student Response**

Student response to this project has been positive. Overall, qualitative information indicates that the students are excited to be using their engineering skills on project with societal benefit. Although no portion of the course evaluation forms specifically asked the students to evaluate this lab, a number of students included written comments regarding the laboratory. One student commented, ”Lead lab was a good idea and was beneficial because it was a real site.” Another student wrote, “I enjoyed every lab especially City Sprouts. It felt like we were getting involved in making a difference.” In the future, quantitative information will be collected to evaluate the impact of this project on the student learning and interest in environmental engineering careers.

The community garden has used the data that was collected to more effectively amend areas with high lead concentrations and to move plants that may be more likely to uptake lead. This project will continue in subsequent years of the course to include testing of other areas of the garden, more detailed studies to investigate lead uptake into different types of plants, and development of an inexpensive test kit for testing vegetables for lead.

**ACKNOWLEDGMENTS**

The authors would like to recognize Jeanine Dickes and Andrew Jameton for their help in developing this project and for allowing us the opportunity to dig around in the garden. Additionally, we would like to thank the entire 2010 Introduction to Environmental Engineering students for their hard work, dedication, and enthusiasm for the project.

**REFERENCES**


