Soil Lead and Soil Organic Carbon Levels within the Springfield, Ohio Community

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ESCI 250

Environmental Research Methods

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24 Nov 2020

Introduction

In many parts of America, including Springfield, Ohio, city security maps were created during the early 1900's to assess the desirability of different neighborhoods for lenders. The security map form contains an "inhabitants" section describing the demographics of each neighborhood. Portions of the demographic contain the negative phrase "the infiltration of...". If African Americans, immigrants, or other minority groups were migrating to the area this phrase was completed with the word "undesirable" (Hoffman et al.). City officials saw minorities living in a neighborhood as a sign that area was unappealing. This led to the city withholding investment in areas they deemed as declining. This racist practice of the divestment of communities with high proportions of minorities has led to serious infrastructural and environmental health inequalities that disproportionately impact present day minority communities. One relevant inequality is the lead pollution in low-income areas (Nemeth and Rowan).

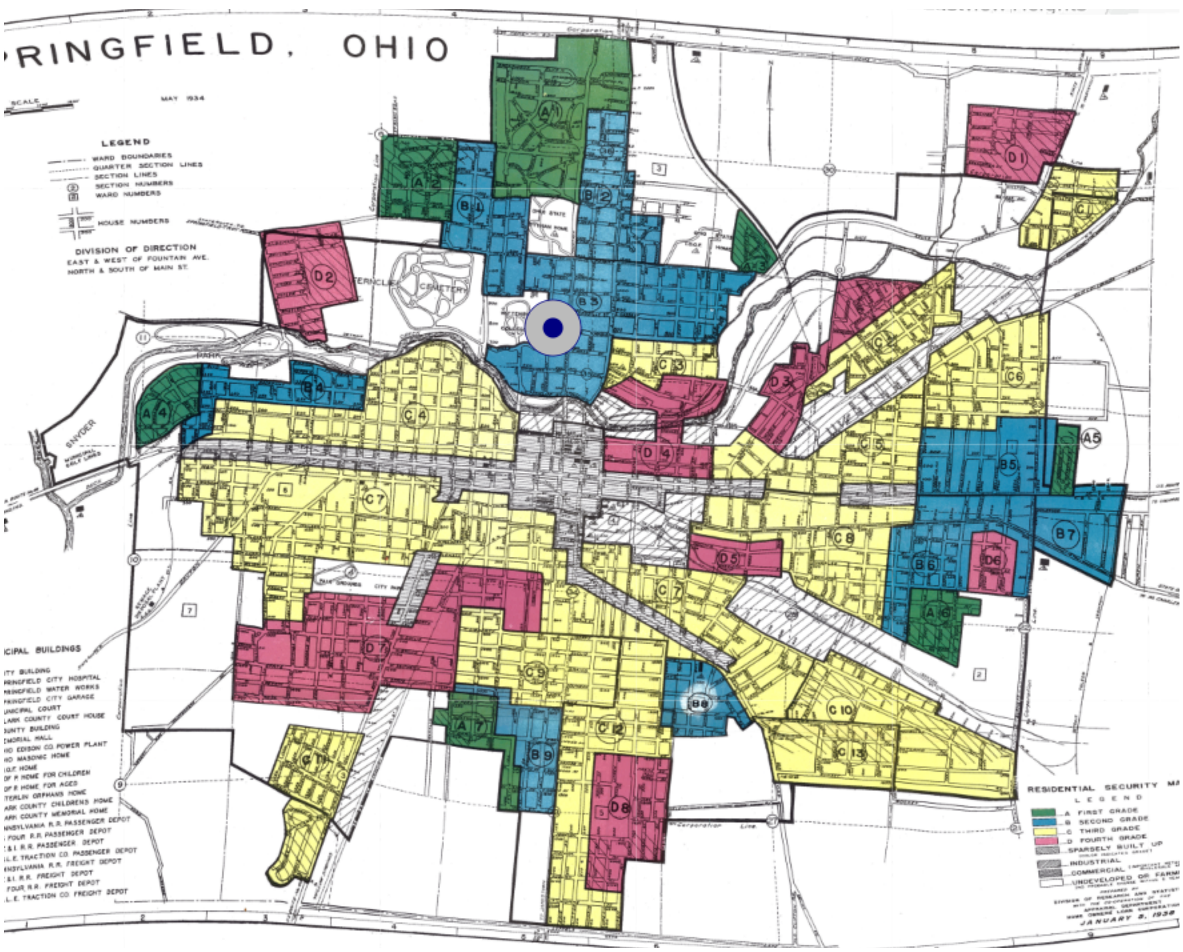


Figure 1. Redlining Map of Springfield, Ohio. Areas are outlined in color by their desirability for mortgage lenders to invest money into the area. Green represents the best places to live, blue represents places that are desirable but not the best, yellow represents areas defined as declining, and red represents areas that are hazardous. The people already living in the area affected its "desirability," as communities with more people of color often received lower ratings, which took money away from the communities over time ("Mapping Inequality").

These communities were affected by the lack of financial investments, as well as the environmental impacts of the forces around them. One of these is urbanization, which reshaped and decreased the quality of impacted soil. This process occurs very quickly, which is vastly different from the millennia it took for the soil to form. The fundamental changes within the soil affects its ecological function. The necessities soil must have to support ecosystem functions are in direct contrast to what soil must be like to support development (Hermann et al.). Natural soils are in good condition for supporting native plants and organisms but are not suited for providing safe and sturdy support for buildings and urban infrastructure. Therefore, as urbanization persisted, grading, excavation, and filling practices altered the soil particle size to be finer and more uniform. It also decreased soil organic carbon content. These patterns were consistent across 11 cities in the United States. Due to these changes, the soil can no longer provide the same ecosystem services it once did (Hermann et al.). Even when urban areas shrink and leave a patchwork of areas that could be developed upon, the soil is so contaminated and worn that it often needs to be revitalized (Schwartz et al.) As a driving force in the inhibition of ecosystem services in developed areas, urbanization and its results present an environmental issue that will continue to have an effect in whichever areas it occurs.

Along with urbanization as an environmental impact, poorer communities are usually more affected by lead contamination. Lead often contaminates soil in low-income or minority neighborhoods because in the late 1800's up to the mid to late 1900's houses were often painted with lead-based paint. In wealthier communities' people could afford to have the lead-based paint dealt with in a safe manner and people in better educated communities were more informed about health problems associated with lead soil pollution (Whitehead). According to the CDC regardless of whether lead is consumed or inhaled it will have detrimental impact. However, inhalation may lead to faster absorption into the bloodstream. Lead is stored in the bones, blood, and tissues of the body. Symptoms of short-term lead exposure may include abdominal pain, constipation, headaches, fatigue, and memory loss. These side effects are intensified from long-term exposure as well, but additional risks include increased disposition for high blood pressure, heart disease, kidney failure, and reduced fertility ("Health Problems").

The CDC also warns against the detrimental effects of childhood lead poisoning, as children are more vulnerable to the effects of lead poisoning because their brains are still developing (Whitehead). These symptoms include damage to the brain and nervous system, slowed growth and development, learning and behavior problems, as well a speech and hearing difficulties. These effects can impede on a child's IQ, ability to pay attention, and success in school ("Health Effects"). An organization in Springfield named the Conscious Connect is a children's welfare and justice organization. It explores opportunities for community gardening and turning underutilized space into areas used for education and culture, to help break any barriers for children ("Declaration of Children's Rights"). In any project moving forward, the organization should consider the risk of lead exposure in its work.

With the risk of lead poisoning, there are different safety standards to consider when moving forward with areas that may contain lead. According to EPA standards, safe gardening limits are below 400 ppm but still pose a potential risk (Latimer et al.). Under 200 ppm is deemed safe for gardening without risks (Filippelli et al.). The other limit to consider is the limits for when children should be around the land, as they are more susceptible to lead poisoning. Soil lead values that are commonly deemed safe for children to play on are below 400 ppm, and the EPA recommends below 1200 ppm for non-play areas ("Environmental Health and Medicine Education").

Our project goals were to collect soil samples from vacant lots and other sites in Springfield, Ohio to determine the concentration of lead and percentage of carbon in these areas. Then, we wanted to use this information to help inform the Springfield Community, specifically people living near the knockdown sites and those using the Houses of Knowledge. We wished to ensure that the residents/visitors of these sites were aware of potential health risks and to help inform the Conscious Connect of soil conditions. The information gathered from this experiment could be used as they pursue community gardening initiatives and investigate the development of other areas. Our hypothesis is that the knockdown sites that were sampled from will have both higher lead content and percentage of carbon than the Houses of Knowledge.

Methodology

To collect our data, we divided up into groups and collected soil samples from either Houses of Knowledge sites or sites where houses had been knocked down. We collected data from the Houses of Knowledge, because of their significance to Conscious Connect. The groups sampled the knockdown sites from a provided list of knockdowns in the Springfield, Ohio area. Our group chose 5 sites that were in a similar area, so we could see if there were noticeable differences from sites near each other, or if patterns were consistent. Each group collected 5 samples from each site they traveled to. We collected our soil samples from the top two inches into the ground to collect adequate lead and carbon data content.

The groups collected 5 samples from different areas around the site to better represent the data coming from that sample location. This gives us a better understanding of the area instead of depending on one soil sample that may not be fully representative, such as a sample having a piece of lead in it to skew the lead presence data or if someone had tried to make a portion of the soil more carbon rich for gardening. A multitude of measurements from each site give a better representation of the site and helps to keep the data from that a site from being skewed.

With the soil collections, we analyzed both the organic matter and lead content from the sites. For organic matter, we allowed the soil to dry first and then weighed them. Then, we burned some (if not all) of the samples, weighed them again, and calculated for the percent organic composition within the soil samples. For lead, we used the XRF machine to analyze the lead content (measured in ppm) within some, if not all, of the soil samples and made a concentration map of the areas with different lead levels (Fig 2). The measurement given plus the possible error were added to provide for the highest possible amount of lead within the soil samples. Then we separated the samples by which safety standards they passed. We put the measurements into a data table and analyzed from there. There were not a lot of replications of the lead content data using the XRF. This means we do not know whether the original lead content readings were precise because we do not have a replication to compare whether a different reading overlaps the original within the range of the error bars. This could negatively impact the quality of the data, as there is no verification that the XRF read the measurements properly.

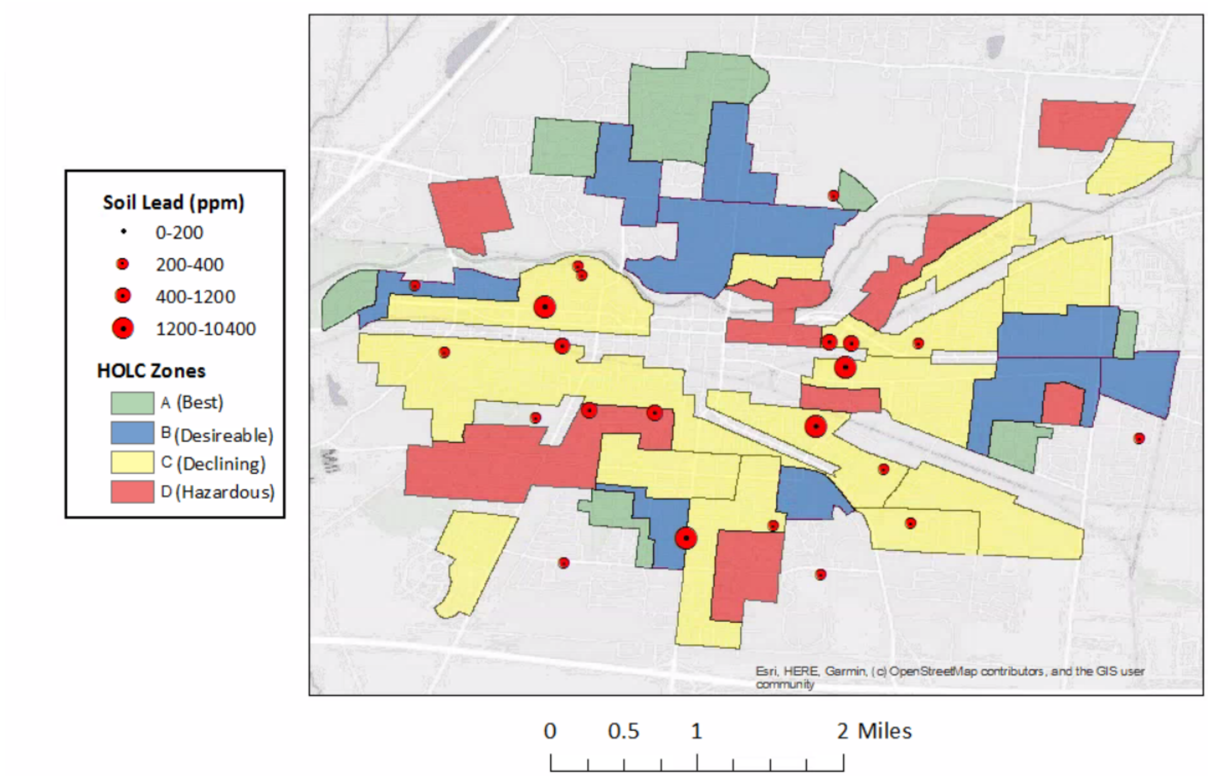


Figure 2. Average Soil Lead Concentration and Redlining Map for Springfield, Ohio. The GIS map depicts the average soil lead concentration for each test site. Larger icons indicated a higher concentration of lead (ppm). Data is overlayed on top of the Springfield, Ohio redlining map to highlight unequal exposure/risks. Most of sites with dangerous lead levels (those exceeding 400 ppm) seem to fall primarily in C (declining) and D (hazardous) zones as historically described by the HOLC. Majority of samples were taken in zones B-D, suggesting that A grade areas have less knockdowns/vacant lots or need for Houses of Knowledge.

Lead Content Results

The knockdown sites have more lead content within their soil with a higher median and mean than the Houses of Knowledge sites. The average may be affected by the high outliers represented in the knockdown data. There are four outliers for the Houses of Knowledge, measuring just above 400 ppm, around 600 ppm, and two above 800 ppm. In contrast, the two outliers for the knockdown sites measure at about 1200 ppm and about 1600 ppm. Despite these outliers, the knockdown sites also have a higher median, which is not affected by outliers. Therefore, overall, there are higher lead levels within the samples from the knockdown sites (Fig 3).

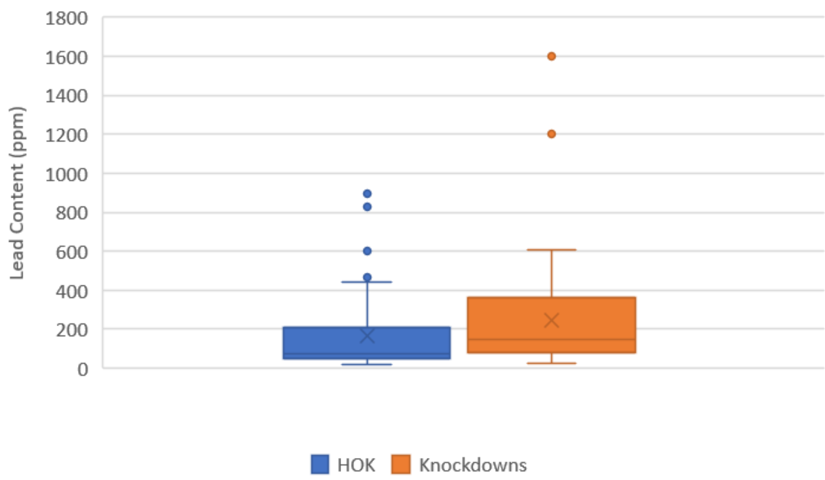


Figure 3. Boxplot of Lead Content in Parts Per Million for the Houses of Knowledge versus Knockdown Sites. The knockdown sites are represented in orange, and the Houses of Knowledge are represented in blue. The knockdown site samples appear to contain more lead than the Houses of Knowledge site samples. Outliers are indicated by dots of the same color for which they are outliers.

The majority (6/10) of the knockdown sites have average lead levels that read above 200 ppm. Of those 6 sites, 4 remained below 400 ppm in average lead content, but two sites measured above that safety standard. No knockdown sites had an average lead content above 1200 ppm (Fig 4). It is worth noting that there were some knockdown site samples did measure above 1200 ppm (Fig 3), but the average for the area was not concerningly high.

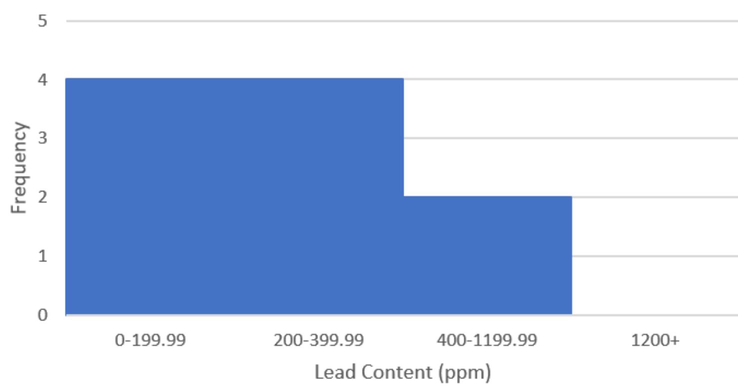


Figure 4. Frequency of Average Lead Content within Knockdown Site Soil Samples. The average lead content (measured in ppm) at the knockdown sites was measured using an XRF machine. At most of the knockdown sites, the average lead content measured above 200. Of the sites that measured above 200 ppm, 2 of those sites measured above 400 ppm.

Two sites measured above 400 ppm. However, the possible error is high and the lowest value takes the levels of both sites back down to slightly above 200 ppm. Meanwhile, the possible error for each of the sites that measured an average lead content below 200 ppm, all remain below 200 ppm, even with the highest possible error. There is one exception, with the highest possible error reaching just at 200 ppm. Meanwhile, the possible error for each of the sites above 200 ppm but below 400 ppm in average lead content, except for one knockdown site, measured below 200 ppm at the lowest error. The exception site also measures above the 400 ppm safety standard at the highest possible error (Fig 5).

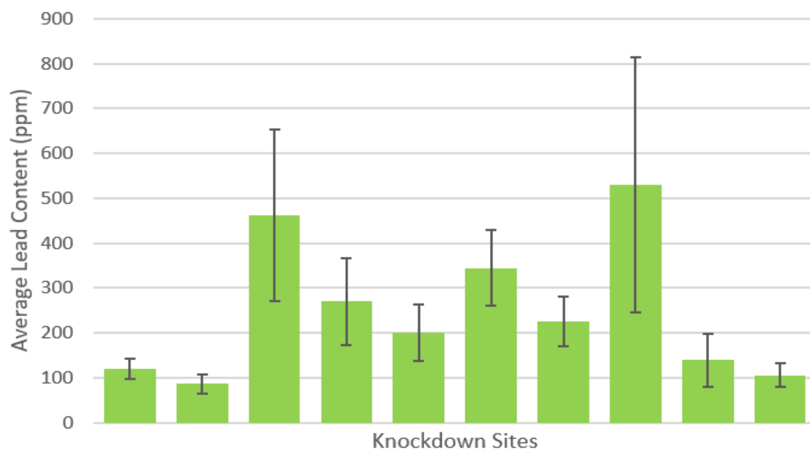
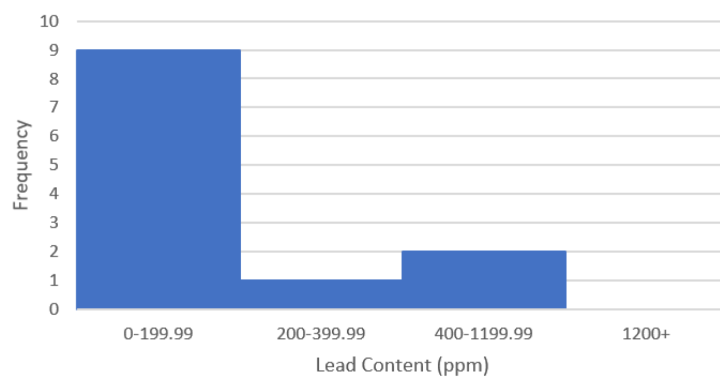


Figure 5. Average Lead Content within Soil Samples at Knockdown Sites. The average lead content (ppm) measured at the knockdown sites was calculated for each site from 5 samples per site. There is variety within the samples, and there are several sites that have an average lead content above 200 ppm. Error bars indicate standard error.

One the other hand, the Houses of Knowledge sites are not as consistently high in average lead content as the knockdown sites. Most of the sites are below 200 ppm in average lead content, with only 3 measuring above that safety standard. Of the three measuring above 200 ppm, one measures below the 400 ppm safety standard, while the other two only measure below the 1200 ppm safety standard. No Houses of Knowledge sites had an average lead content over 1200 ppm (Fig 6) nor did they have any specific soil samples that measured above 1200 ppm (Fig 3).

Figure 6. Frequency of Average Lead Content within Houses of Knowledge Soil Samples. The average lead content (measured in ppm) at the Houses of Knowledge sites was measured using an XRF machine. At most of the knockdown sites, the average lead content measured above 200. Of the sites that measured above 200 ppm, 2 of those sites measured above 400 ppm.



Even at the highest possible error, all of the Houses of Knowledge sites that measured below 200 ppm for average lead content remained under that safety standard. The error for the site that measured between 200 ppm and 400 ppm did measure below 200 ppm at the lowest possible error and did not reach above 400 ppm for the highest possible error. The two Houses of Knowledge sites that measured above 400 ppm still measure above the 200 ppm mark even at the lowest possible error, but are no longer above the 400 ppm safety standard (Fig 7). For both knockdowns and Houses of Knowledge, sites that had higher measurements of average lead had larger possible errors. These sites are likely where the soil samples that measured as outliers in their respective data sets were found.

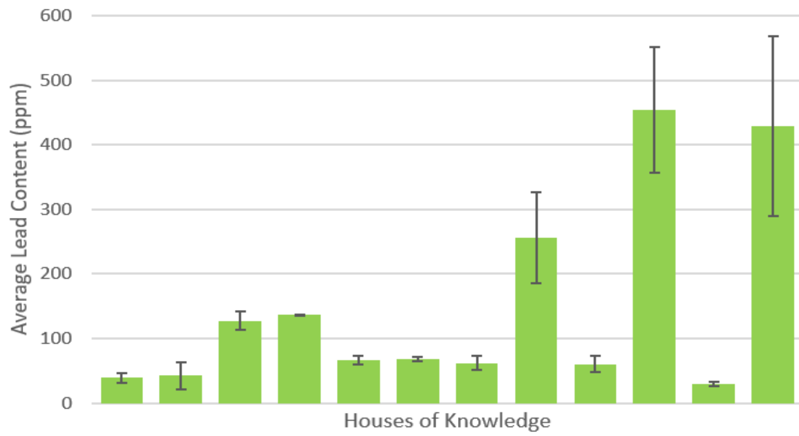


Figure 7. Average Lead Content within Soil Samples at Houses of Knowledge. The average lead content (ppm) measured at the knockdown sites was calculated for each site from 2 or 5 samples per site. Most of the Houses of Knowledge sites have lead content below 200 ppm, with only 3 sites measuring an average above that measurement. Error bars indicate standard error.

Percent Carbon Results

The knockdown sites also have a higher carbon percentage, though it is closer than the lead content differences in average because of the variety within the Houses of Knowledge sample data. There are no outliers in the data, so it is unlikely that the means are skewed. However, the median for percent carbon for the knockdown sites is significantly above the median for the Houses of Knowledge, meaning that the knockdown sites have more sites with a higher average percent carbon that the Houses of Knowledge do (Fig 8).

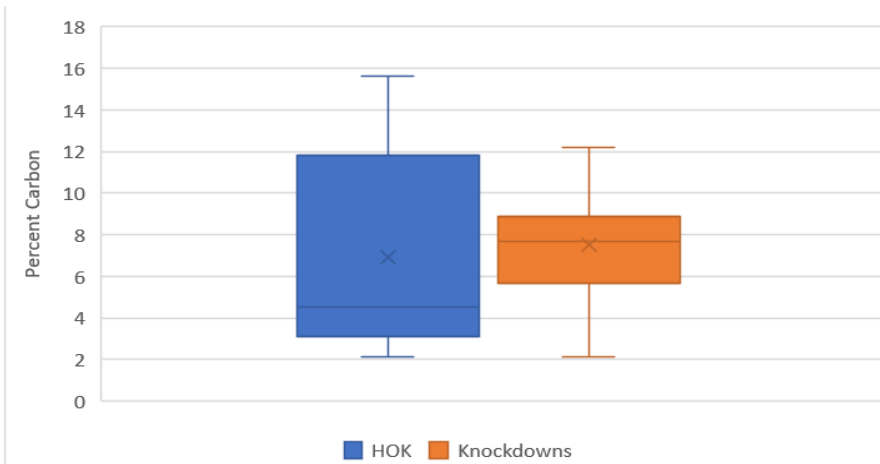


Figure 8. Boxplot of Carbon Percentages for the Houses of Knowledge versus Knockdown Sites. The knockdown sites are represented in orange, and the Houses of Knowledge are represented in blue. The Houses of Knowledge have more variety within the data, but the median for the knockdowns is higher than the Houses of Knowledge.

The average percent carbon at the Houses of Knowledge sites ranges from between about 2% to about around 14%. However, this is primarily because there are two groupings of percent carbon measurements. Most of the sites (8/12) are between 2% to about 4% average carbon, but there are 4 sites that measure between 12% to about 14% for their average carbon levels. Even with standard error, the two groupings do not change, because most of the sites have a low standard error that would not change the measurements to the average percent carbon levels even at the highest or lowest reading. The sites with a lower percentage of average carbon remain between 2% average carbon at the lowest standard error and 6% average carbon at the highest standard error. The sites with the higher percentages of average carbon remain between 10% average carbon at the lowest possible error and 16% average carbon at the highest possible error (Fig 9).

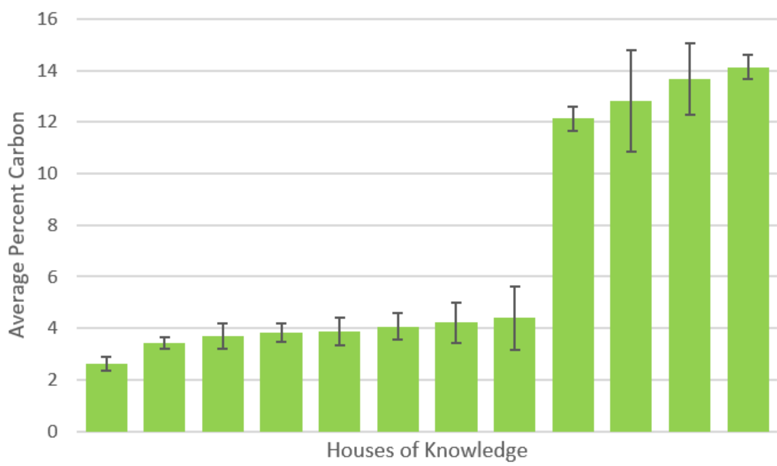
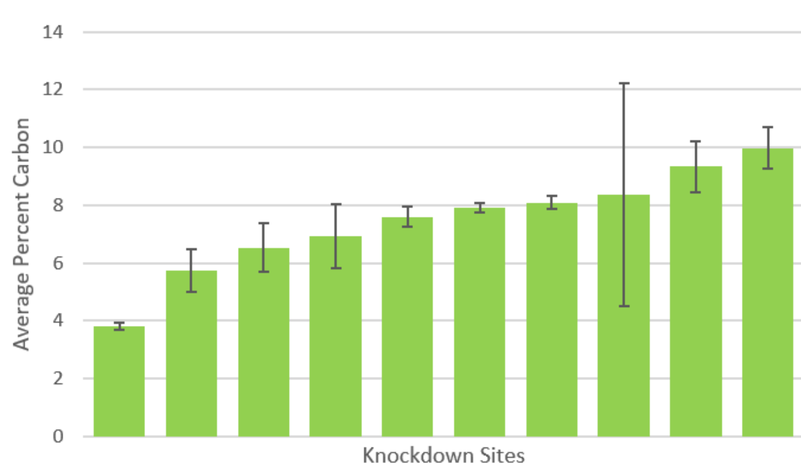


Figure 9. Average Percent Carbon within Soil Samples at Houses of Knowledge. The average percent carbon measured at the houses of knowledge was calculated for each site from 3 samples per site. There are two groupings of carbon percentages with a significant distance, about 8% between them. Error bars indicate standard error.

For the knockdown sites, the percent carbon ranges from just below 4% average carbon to right about 10% average carbon. There is more variation between the different sites instead of the two groupings like the Houses of Knowledge have. Most of the knockdown sites average carbon levels range between 6% to 10%. The lowest values, just below 4% average carbon and just below 6% average carbon, are the only knockdown site measurements not within that range (Fig 10).

The addition of standard error changes most of the numbers very little. At three sites, the lowest possible error brings the average level of carbon to below 6% but still above 4%. At two sites, the highest possible error pushes them above 10% average carbon. However, at one site, the standard error is very large; with the lowest possible error, the site measures at just above 4% average carbon, but at the highest possible error, it measures at just above 12% average carbon. The other four sites have such small errors that they would not cause any major changes in average percent carbon at the highest or lowest error (Fig 10). Overall, the four Houses of Knowledge sites above 12% carbon in the soil have the highest percentages of average carbon, however, the other Houses of Knowledge sites account for the lowest average carbon percentages as well.

Figure 10. Average Percent Carbon within Soil Samples at Knockdown Sites. The average of the percent carbon measured at the knockdown sites was calculated for each site from either 2 or 5 samples per site. There is variation among the different sites, however there is no definite trend. Error bars indicate standard error.



Discussion

Lead concentrations were nearly two times as high in soil from knockdown sites compared to soil samples from Houses of Knowledge. Only four knockdown sites would be safe for gardening not based on EPA standards. The other six sites exceeded the average lead content of 200 ppm. Only two of those six sites exceeded the EPA safe gardening standard, however, so according to EPA regulations the sites that are still below 400 ppm could still be used for gardening; there would be a potential risk for these areas, however. These sites would also be safe for children play areas; however, the sites that exceed 400 ppm would not be suitable for children to play in, nor would they be suitable for gardening. All the sites were below the 1200 ppm safety standard for non-play areas and are thus safe in that regard. Some of the samples from the sites were above the 1200 ppm safety standard for non-play areas and would therefore, be in danger of causing possible lead poisoning even if the average lead content at the site was below the safety standard.

The Houses of Knowledge have lower average lead content overall than the knockdown sites. Almost all of the Houses of Knowledge sites have an average lead content below the 200 ppm safety standard for gardening not based on EPA standards. Only 3 sites exceed the 200 ppm safety standard. One of those does stay below the EPA safe gardening standard of 400 ppm, but the other two sites exceed that standard. Neither of these sites, therefore, would be good sites for gardening. Because one of those sites is a gardening area, it will probably be necessary to move this gardening site to a different area. Neither of these areas would be safe for children to play in either, as they exceed the 400 ppm safety standard. However, with the large possibility of error, it would be best to have a more thorough experiment for both areas, regarding lead content within the soil, to verify the current results and make changes from there. As with the knockdown sites, none of the sites exceed 1200 ppm, the safety limit for non-play areas.

While it seems that there was a greater percentage of carbon in the soil samples at the Houses of Knowledge because there is a larger variety within the data, the median and mean were still higher for the knockdown sites, which suggests that they have the higher percentage of carbon in the soil overall. Four of the Houses of Knowledge sites, however, have the highest average carbon percentages of all the sites, both knockdowns and Houses of Knowledge. These sites have the best soil for growing and gardening. Overall, though, the knockdown sites would be considered better for growth, regarding their average carbon percentage in the soil, as the majority of the Houses of Knowledge sites have low percentages of carbon. However, due to the higher lead content within the knockdown sites soil, knockdown sites are likely to be more unsafe for gardening. Some of the knockdown sites are below EPA safety standards for safe gardening and also have higher average percentages of carbon. These sites might be possible areas for gardening if there is need for future growth.

There are potential solutions to the issue of soil lead contamination regarding community gardening. A garden area with threatening levels of soil lead may put the gardeners or citizens who utilize it at risk of soil lead inhalation or ingestion. There are several practices to help avoid lead exposure related to gardening and its adverse health effects. One of these is raised bed gardening, where boxes are built on top of the ground and filled with uncontaminated soil.

Another method of prevention is using fertilizer with phosphate that changes lead into a less soluble form (Schwarz et al). Urban gardening also has the potential to eliminate or reduce the risk of lead exposure overall. Adding organic matters to the soil tightly binds the lead and decreases its concentration. Also, addition cover from the plants or maintenance like laying down straw or mulch reduces the chance of dust containing lead from being distributed by the wind (Schwarz et al).

There are multiple directions in which to further this project. First, we would recommend there be further study into the areas with large error bars/outliers in their data. More samples and additional analysis of the soil and lead levels in these areas would increase confidence in their safety and community potential. The project may also explore the soil lead contamination mitigation practices briefly described above. This could include more research or an experiment to test each methods effectiveness.

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