Grounded Strategies

2021 Biochar Report

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Background of Biochar

Biochar is a black carbon, produced specifically for soil amelioration or remediation. It is very similar to charcoal and is formed after biological residue is combusted, a process known as pyrolysis, under low-oxygen conditions[1]. Biological residues that can be used include wood, manure or compost, and crop or plant matter. Different types of materials result in different types of biochar which are then used to produce different effects on the soil and crops.

The creation and technology around biochar has been celebrated as a new scientific invention, however, biochar has a long and complex history as it is rooted in indigenious soil practices in the Amazon Basin[2]. It is important to recognize this and not erase its history, which is being done in the modern scientific community. Terra Preta de Indio, also known as Amazonia Dark Earth, is a very fertile artificial soil found throughout the Amazon and Brazil created by indigenous civilizations over 2500 years ago[3]. Scientists attempted to recreate Terra Preta, due to its high carbon content and carbon storage capacity for carbon sequestration and soil fertility, which inspired the development of biochar.

Biochar has many uses and benefits but is mostly used for soil management and conditioning as it improves the soils' chemical and biological properties. Biochar can be used for soil remediation or reversing soil pollution caused by heavy metals and metalloids, nutrient management, soil health and biodiversity, and climate change mitigation for soil carbon storage[4]. Biochar as an amendment can increase cation exchange capacity, which is the number of positively charged ions on the soil's surface which hold soil nutrients, increase surface area, increase soil pH or the acidity of the soil which affects crops, increase nutrient availability, and water holding capacity[5].

Pittsburgh's Lead Problem and the Potentials of BioChar in Lead Remediation

History of Lead

Elevated lead presence in Pittsburgh and Allegheny County stems from the historic use of lead in gas, paint, pipes, and other industrial applications.[6] During the late 1970s laws and regulations to stop lead-use allowed for the dramatic decrease and

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[1] https://www.sciencedirect.com/science/article/abs/pii/S0269749111003939
[2] https://www.tandfonline.com/doi/abs/10.1080/1523908X.2016.1269644
[3] https://www.tandfonline.com/doi/abs/10.1080/1523908X.2016.1269644
[4] https://onlinelibrary.wiley.com/doi/epdf/10.1111/sum.12693
[5] https://extension.tennessee.edu/publications/Documents/W829.pdf
[6] https://alleghenycounty.us/uploadedFiles/Allegheny_Home/Health_Department/Programs/Special_Initiatives/Lead/Lead-Task-Force-Report-Dec2017.pdf

halt of the output of lead based housing and industrial application, but Allegheny County is documented to have 80 percent of houses built prior to 1978.[7] Homes built prior to 1978 signify higher risks of lead exposure to populations living in Allegheny County today.

In addition to lead exposure in homes, high levels of lead contamination is prevalent in soil in Allegheny County. Elevated concentrations of lead stem from the increased demolitions of homes built prior to lead regulations, allowing for lead to concentrate in soil of vacant lots where these homes once stood.[8] When these homes were demolished, proper lead-safe wetting methods to decrease lead concentrations were not used, allowing for lead dust plumes that spread hazards as far as 400 feet away from the worksite.[9]

<u>Dangers of Lead</u>

High lead levels pose a threat to residents' health and safety. High lead exposure can cause damage to the nervous system, slowed growth and development, learning and behavior issues, and hearing and speech issues.[10]

Higher levels of lead concentrations, due to an increased occurrence of vacant building demolitions, are disportionately higher in African-American majority neighborhoods like Homewood[11] Exposure to health hazards for these communities of color are exacerbated by these demolitions.

Contaminated soil can be tracked into homes on shoes and clothing, or can be blown as dust and ingested. Children playing on lots could put contaminated soil in their mouths through normal hand-to-mouth behaviors. Lead cannot be seen, so a child may unknowingly play on a lot with lead contamination. Play areas for children become hazardous when lead contaminated soil is above 400 parts per million with 1,200 parts per million.[12] In the Allentown neighborhood of Pittsburgh, contaminated

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[7] https://alleghenycounty.us/uploadedFiles/Allegheny_Home/Health_Department/Programs/Special_Initiatives/Lead/Lead-Task-Force-Report-Dec2017.pdf

[8] https://alleghenycounty.us/uploadedFiles/Allegheny_Home/Health_Department/Programs/Special_Initiatives/Lead/Lead-Task-Force-Report-Dec2017.pdf

[9] https://pubmed.ncbi.nl m.nih.gov/24179257/

[10] https://www.cdc.gov/nceh/lead/prevention/health-effects.htm

[11] https://www.post-gazette.com/opinion/Op-Ed/2016/08/26/Getting-the-lead-out-of-communities/stories/201608310066

[12] https://www.post-gazette.com/local/city/2019/05/27/Lead-soil-levels-Allegheny-County-Allentown-pittsburgh-Abiding-Ministries-Hilltop-Alliance/stories/201905170107

lead levels were above 1,200 parts per million. The Allegheny Health Department has documented 1,763 children between 2015-2018 had elevated blood lead levels.[13]

Biochar as a Solution

As noted in the background section, biochar is used to help manage soil to improve soil chemical and biological properties. In this Pb+G project, analysis was performed to determine the effectiveness of biochar used to remove lead in soil with high concentrations of lead. Studies have shown that with the addition of biochar in lead-contaminated soils resulted in a decrease in soil lead availability and lower lead concentrations overall.[14] The increased lead concentration in Pittsburgh specifically on vacant lots indicates the need for a simple way for lead removal. Biochar is a viable solution to decrease lead contamination in soil without the need for a great deal of soil manipulation.

Economic/Financial Cost

Advantages of biochar to remove concentrations of lead are not limited to the simplicity of the process and environmental benefits, but also includes the cost advantage. The physical removal of lead contaminated soil is a common alternative when trying to ensure a decrease of exposure to the health hazards of lead.
The Environmental Protection Agency recommends the removal of soil that is contaminated to depths greater than 12 inches and covering with clean soil when it is cost effective as it is considered a permanent remedy to lead toxicity issues. Other recommended solutions by the EPA include covering the ground with 12 inches of clean soil to create a barrier for general residential yard use and covering with 24 inches for gardening.[15]

This process of removal and clean fill includes the labor costs for the removal of the hazardous lead contaminated soil, the overall cost of the soil removal equipment, and the price of soil replacement. The cost of removal and fill can vary greatly depending on the size of the lot, how much soil is filled, and labor. Average costs of excavation, removal, and fill of clean soil costs on average between $6,000 to $10,000 per triple backyard. [16]

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13 https://www.alleghenycounty.us/Health-Department/Programs/Special-Initiatives/Lead/Lead-in-Allegheny-County.aspx

14 https://www.nature.com/articles/srep31616

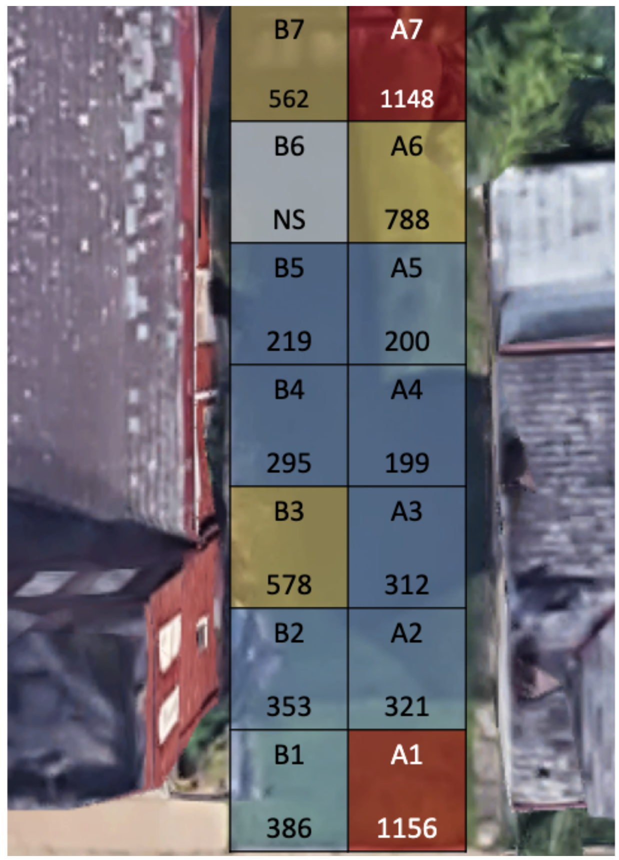
15 https://semspub.epa.gov/work/HQ/175343.pdf

16 https://www.preventioninstitute.org/sites/default/files/editor_uploads/images/stories/Documents/Boston_MA_Lead_Safe_Yards.pdf

In contrast to the physical removal of soil, the biochar solution for lead contaminated soil remediation is less invasive. Biochar remediation process is lower in cost of labor and supplies since it mostly calls on de-sodding the top layer of soil, carefully placing it aside, adding in the biochar, placing the top layer back on, and then covering with mulch on the lot. This process does not include the physical removal of contaminated soil as the biochar is meant to improve existing soil chemical and biological properties.

735 Excelsior St
Grids are 10ft. x 10ft.
14 samples

Lead Level	Range
0 to 150ppm	None
151 to 400ppm	Low
401 to 1,000ppm	Medium
Greater than 1,000	High



The vacant lot called for an amount of biochar for a small 10ft by 10ft plot of land on the lower right corner of the lot. Overall the cost accumulated was $300 for (6) 5-gallon buckets of biochar for a depth of 0.5-1.5 inches for the 10ft by 10ft plot. Below is the cost breakdown of the biochar technique.

Breakdown	Pb+G(rounded) Project Costs for 100 sq feet
Labor Costs	4 hrs x $55-$70 per hr
Soil Removal	-
New Soil	-
Biochar	$300 (0.15 cubic yards)
Mulch	$31 per cubic yard (1 Cubic Yard per 10ft x 10ft plot)
Perennials	$145
Edging	$220
Rough Estimate	**$916- $976**

With this cost breakdown being solely focused on a 10ft by 10ft (roughly 100 sq. feet) plot it is important to consider what the cost would look like if we were to scale up to remediate the entire lot. If the cost for 100 sq. ft is around $696- $756 and the size of the entire lot is roughly 1,830 sq with (14) 10ft by 10ft sampling squares we would be looking at the entire lot cost to be closer to $12,824-$13,664. This cost of course includes hardscapes and softscape materials and assumes there would be a large perennial bed. If this were just to be done with biochar and mulch it would be closer to $7,714-$8,554. All of our purchases were made with new materials and we had very few to any donations. The relative costs, of course, would go down drastically with the donation of materials such as mulch, perennials, edging, and the biochar or through bulk purchasing for projects of a larger scale.

Project Breakdown: Pb+G

<u>Choosing the Site</u>

In response to the high levels of lead in the soil in Pittsburgh, Grounded Strategies proposed an environmental justice initiative called Pb+G(rounded): Reducing Lead Toxicity in Vacant Lots. The goal of this project was to install and test out a low-cost remediation apparatus on a vacant lot as a way of reducing the toxicity of lead. We initially proposed to conduct this experiment on a vacant lot in the neighborhood of Allentown on 51 Millbridge Street. Unfortunately due to issues with obtaining access agreements to the site due to lead levels being over the limit of the Adopt-a-Lot requirements we had to shift our project to a new lot.

Fortunately, we were able to partner with Abiding Missions, a holistic, urban, grass-roots organizing body, trained in trauma-informed care and mental health and a base for community development, leading projects grounded in the practices of restorative justice, and utilize the lot adjacent to their church on 731 Excelsior Street. Based on initial soil sampling, the lot had very high lead levels (>1,000ppm) and was a cause for anxiety in the neighborhood.

With funding support from the Environmental Protection Agency, we decided to proceed forward on utilizing the lot to test out a lead remediation apparatus. At the time, we had the intent of testing an apparatus with a combined earth battery and composting pit to change the chemical composition and toxicity of lead in the soil. However, due to restrictions and regulations required on the batteries usage, we decided to utilize biochar. As mentioned above, biochar has numerous benefits to soil health and quality and studies have found capabilities of biochar in reducing lead toxicity in soil.

<u>Installation and Methodology</u>

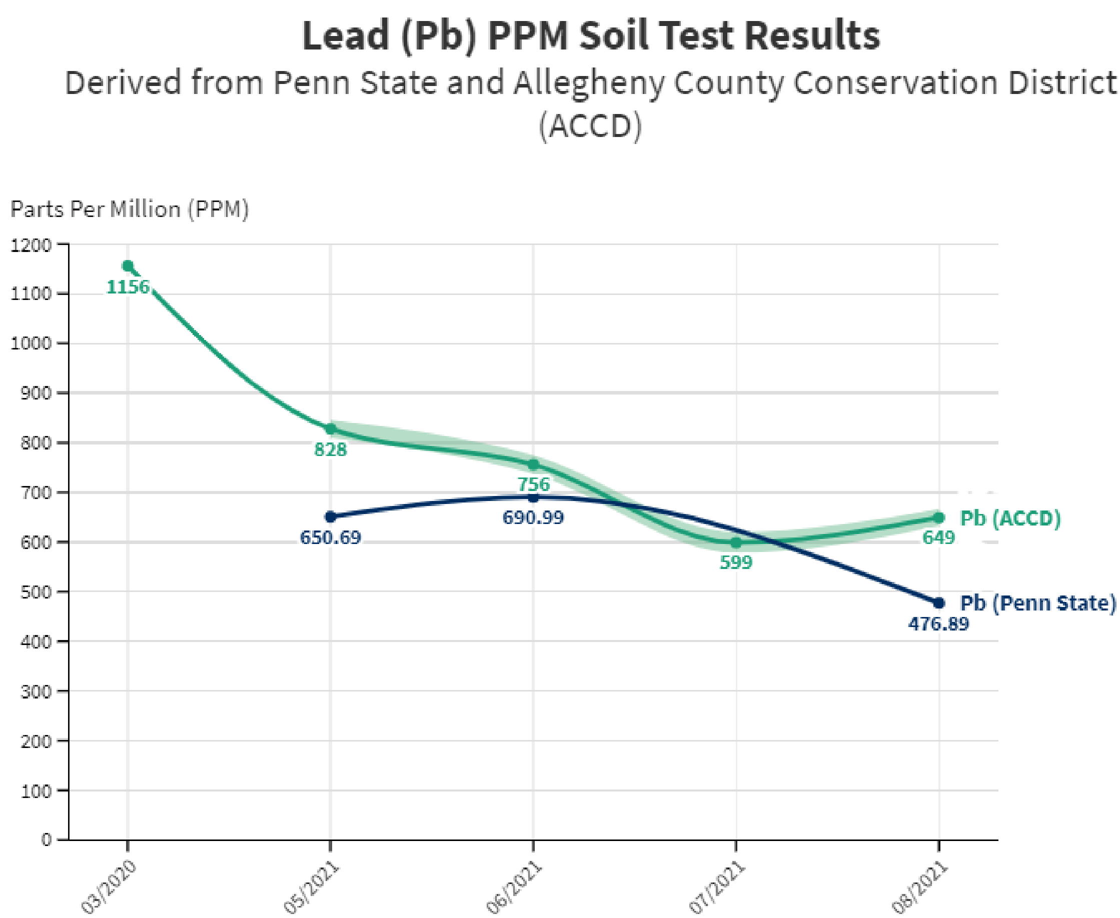
Starting in May 2021, we broke ground at Abiding Missions on a 10’ by 10’ plot of land at the right front section of the lot. We worked to desod and break up the ground so we could mix in the biochar. We mixed in 30 gallons of biochar, added the soil that we pulled out back into the plot. After letting the soil settle, we came back to the site, planted perennials, laid out a brick edge, and covered the plot with mulch to retain moisture and decrease disturbance of the soil.

Since adding the BioChar back in May, we have collected soil samples once a month up until August 2021. We utilized two testing labs to analyze our soil, with support from a XRF gun utilized by Jon Burgess at Allegheny County Conservation District and Penn State University’s Agricultural Analytical Services Laboratory (AASL).

Lead Analysis

Graphs and Tables

Date Soil Sample Taken	Pb (ACCD)	Lower Bound Confidence ACCD	Upper Bound Confidence ACCD	Pb (Penn State)
Mar-20	1156			
May-21	828	810	846	650.69
Jun-21	756	737	775	690.99
Jul-21	599	578	620	
Aug-21	649	632	666	476.89



Results

While the team did find a varying level of error in our results, overall sampling has resulted in a reduced lead toxicity of the experimental plot. As seen in the graph found above, we ran two analysis processes to compare the same sample months. Our starting sample, which was collected back in April 2020 and tested by Allegheny County Conservation District (ACCD), had shown a high level of 1,156 ppm of lead which often would cause residents to no longer be able to access City-owned lots. Since our initial sampling, we had a delay in the project due to COVID-19 and had not installed the apparatus until May 2021. We took one last comparison sample in May 2021 before we installed the bioChar amendment.

As mentioned previously, we continued sampling once a month to compare the levels of lead toxicity in the soil. We initially started our testing through ACCD to continue off the analysis process conducted on prior samples but once we received the May 2021 results back and saw a drastically different level of lead compared to April 2020, we decided to cross analyze and have the samples be tested by the Penn State University's AASL as well. Based on the starting sample results from April 2020 of 1,156 ppm we see a 507 ppm reduction in lead from our August 2021 ACCD results and a 679 ppm reduction from August 2021 AASL results. In comparison if we are to base it off of our May 2021 sample tested by AASL and ACCD to the August 2021 sample we see 179 ppm difference with ACCD and a 173.8 ppm difference with AASL.

<u>Error</u>

In research there are three types of error that can occur, systematic error, random error, and blunders. Systematic errors are errors introduced by an inaccuracy to the system. This includes instrumental errors that arise from the instrument or machinery itself, experiential technique/procedural errors that are made throughout the experiment, and larger external conditions that impact the experiment such as the environment. Random errors are caused by an unknown or unpredictable change and do not always have an identifiable source. This includes uncontrolled or third variables, observer errors, and random variation. In science, blunders are outright mistakes that are not frequent enough to be random errors and cannot be analyzed in the way other scientific errors can.

In this experiment, systematic errors and random errors are the main issue of focus. For systematic errors this includes errors in the soil collection or testing process and the machinery involved such as the XRF gun, soil oven, larger environmental factors that impact the pre-existing soil conditions such the soil composition, errors in data collection or calculation, and the length of the experiment itself.

Random errors include sampling errors which is statistical error that occurs when a sample taken is not representative of the population and other extraneous variables that could have impacted the results of the testing such as dead chickens and cat feces.

Overall, the largest errors of concern are the extraneous variables that impacted the soil and the length of the experiment. Additional soil pretests, multiple soil testing samples, and a longer experimental time-frame with no large break in the middle would have been beneficial to this experiment's reliability and validity.

Outcomes and Takeaways

Previous Biochar Success

As addressed in the background, biochar is a new and emerging soil remediation technique with varying levels of success. Previous research studies have shown biochar to be a viable tool in reducing soil toxicity which informed our decision to use it in our experiment. While our test results may have some variation, there is still a noticeable reduction in lead toxicity with around 173.8 and 178 ppm differences in both sampling processes. With a long sampling period we may be able to see a more significant reduction.

Our Limitations

As discussed in the errors and results, this experiment ultimately needs a longer sampling period for a more viable analysis and double testing throughout for increased validity and reliability.

Economics Costs

From the project costs breakdown, we see that the financial cost for testing this with similar conditions on a larger lot would range closely to or above the average costs of soil replacement for a backyard. While the costs here are higher than the average cost of soil replacement, if this were to just be scaled down to be used solely as a remediation tactic to stabilize the soil health and reduce lead toxicity we would see a drastically lower price.

Overall Results and Next Steps

While this round of Pb+G is coming to a close for the year, we were able to have a number of outcomes and realizations throughout the program in Allentown. To first take a look at the past success of other biochar experiments, we find hope in its ability to consistently improve soil health and quality. Biochar products have been used for thousands of years as a "forever compost," its multifactor ability to remove heavy metals from the soil while maintaining nutrients needed for plant growth point towards a win-win solution for the problem of lead filled soil in Pittsburgh. However, there are still limitations that require more time and investment.

After addressing the possible sampling errors we find a need for further experimentation through a longer sampling period. In future tests of the biochar we hope to examine its remediation capabilities through at least a year-long sampling period after the apparatus is installed. This would allow for a more consistent and higher quality result of the reduction of lead toxicity in the soil. While there was possibly a bit of human error in the sampling process and site stabilization, it is necessary to remember that implementation of this kind of apparatus on a publicly focused lot can result in larger human interaction and variation of site factors. With this not being done in a lab setting, it is normal for these outside variables to happen.

When working with communities that are most vulnerable to environmental racism and economic inequity we need to ensure that we are providing accessible solutions. While the overall cost of labor and materials for remediating is cheaper and overall safer than excavating and replacing topsoil it is necessary for more investment to be targeted towards making biochar a more cost effective and affordable alternative to just putting down mulch on lead filled soil. With further development of biochar production, there is a possibility of making this an even more economically viable option.

While there is still space for future Pb+G(rounded) projects to live on, we need to more importantly start thinking about the long term plan for City-owned vacant lots that have high levels of lead. The lead problem in Pittsburgh comes from many sources including water, dust, paint, and soil so we must think about taking preventative and reactive solutions to reduce exposure and harm. We must take a holistic approach to this issue and think about the causes of lead in soil.

We know that unregulated demolition practices of lead painted homes has produced this problem of lead toxicity in vacant lots and so there must be prevention of future vacant lots being filled with lead. Alongside the use of safe practices such as wet-demolition methods to remove future risk of lead filled soil there should be more funding and investment in remediating lead filled vacant lots.

While covering with mulch and grass is an important short term solution, in order for these lots to become assets to the community they need to be remediated and renewed. The City of Pittsburgh needs to have a process in place in order to stabilize these lots and make them less of a risk to the community around them. We recommend that there should be further experimentation of lower cost remediation tactics, such as biochar, to not only increase the viability of the soil health.

Any level of exposure to lead in children is dangerous and we must eliminate any chance of exposure. These vacant lots can not be ignored or boarded up, we must work together to turn them into safe, valuable, and accessible spaces with communities.