

Healthy soils are the backbone of our food supply. Yet in many urban gardens, these soils are tainted with a heavy metal called lead, a serious danger, especially for children.

The soils research cluster lab at Penn State is working on a solution that utilizes biochar to reduce the risks of lead contamination.

My name is Cara Bintrim. I'm a graduate student at the soil research cluster lab at Penn State University. I'm working with biochar, which is a specific type of charcoal that's been used since ancient times, but has recently gained popularity in the field of soil science.

In our lab, we are working on functionalizing biochar or modifying its properties by heating it in the presence of oxygen. I grew up in Johnstown, Pennsylvania, which is in the middle of the rust belt. I have seen soil contamination all around me my whole life. I was drawn to this project because biochar seems like a promising amendment to help remediate such contamination.

Biochar, similar to charcoal, is a carbon-based material produced by heating plant or animal residues in a low oxygen environment. This is a process called pyrolysis. Pyrolysis is not burning as combustion does not actually take place. It is more like baking but with the absence of oxygen. In contrast to charcoal, biochar is heated to much higher temperatures so that volatile organic compounds are released.

Here in Pennsylvania, Metzler Forest Products separates and burns the volatiles from their biochar production process to provide heat for the treatment of firewood.

So some number of years ago we had opportunity to enter the packaged firewood business which requires that you heat treat the wood to kill pests for transportation. Before this biochar machine showed up, it was being operated on propane. So we have displaced several thousand gallons of propane every year for the firewood process with the heat from the biochar machine.

Biochar has unique properties that make it valuable for soil health. First, it is highly stable carbon that resists microbial decomposition. It can store carbon in soil for hundreds of years. Second, its porous structure acts like a sponge, holding water and nutrients. Third, its alkaline pH can reduce soil acidity and act as a liming agent. Finally, biochar is reactive towards soil contaminants, including lead, helping to immobilize them in the soil.

Biochar can be made from a variety of materials which are known as feedstocks. Each has advantages. Manure biochar contributes valuable nutrients such as phosphorus and calcium. Crop residue biochar is an economical choice, and wood biochar offers the greatest potential for high surface area.

Our feedstocks are mixed hardwood chips um that could come from a sawmill or could be made from material just like this. And then sawdust from our firewood manufacturing process. The feedstock runs through the oxidizer where the volatiles are released and that material drops down into the rotary kiln, sloshes around in the kiln for about 30 minutes at 725°C. When it gets to the end of the rotary kiln, we hit it with water to quench that process so that the material doesn't continue to process and turn into ash. And then we also believe that the the water hitting material at 725 degrees Celsius produces steam and kind of expands and increases the surface area.

Lead immobilization by biochar is achieved through several mechanisms. One, the biochar can trap lead ions in its pores. Two, biochar can bind ions to its functional groups. Three, biochar can precipitate lead with minerals such as phosphates. Four, biochar can exchange other cations for lead cations ions. These mechanisms should all help to reduce the bioaccessibility of lead to people, therefore lowering exposure risks.

Scientists have developed several techniques to improve this binding of lead by chemically treating the biochar. We can add functional groups using chemical oxidation or impregnate the biochar surface with iron or manganese oxides to enhance lead absorption.

At the soil research cluster lab at Penn State, we are demonstrating the effectiveness of using just heat and oxygen to modify biochar.

Biochar is produced in a low oxygen or no oxygen environment. So by heating it in the presence of oxygen, we are able to add functional groups to the surface of the biochar, therefore increasing absorption of lead. For the modification process, we load wood biochar into cast iron trays, spreading about three cups in a thin, even layer. Trays go in a furnace at 300° for about 3 hours. The heat treated biochar is placed in a desiccator to prevent the absorption of moisture from the air as it cools. After heat treatment, we compare the pH of treated biochar to the original biochar. We do this because pH is an indirect indicator of the presence of acidic functional groups on the surface of the biochar, which should help bind lead. To test the absorption of lead to biochar, we add a solution of lead nitrate to 0.1 g of biochar and allow it to incubate on a shaker overnight. The next day, the mixture is filtered through filter paper and then through a 0.45 micron syringe filter to remove any solids. Next, we need to determine how much lead is left in the solution. For this, we use X-ray fluorescent spectroscopy. We first prepare a sample cup which has transparent film under the sample so that the instrument can detect the elemental composition. We pipet 3 ml of sample into the cup. Finally, we load our samples into the X-ray fluorescence spectrometer to obtain lead measurements. From these measurements, we can calculate the amount of lead that was taken up by the biochar and compare the absorption capacities of untreated and treated biochars.

Our results have shown a clear difference between heated and unheated biochar's physical and chemical properties as well as an increased absorption of lead in heated biochar. The next step will be adding the biochar to the soil to see how this reaction plays out in the soil environment.

Another consideration is the upscaling of this modification technique. We asked Metzler how a biochar facility like theirs could add a heat treatment to the manufacturing process.

You could take the process heat and put that into I'm going to say a dryer of some kind. Um, and control the temperature to whatever you want. Run the biochar back through. So, it would be like a bolt-on process.

Biochar is both an ancient and modern tool. From traditional methods to high-tech facilities, biochar offers a sustainable way to improve soils, store carbon, and potentially immobilize contaminants like lead. We hope that this project inspires new conversations, new experiments, and new collaborations in the growing field of biochar research.