Phytoremediation of Heavy Metal Contaminated Soils

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Abstract

Heavy metal contamination in urban soils poses a threat to both humans and the environment. Analyzing the health of soil can be advantageous to the environment and humans because soil is the foundation of both agricultural productivity and water quality. A widely used method to uptake heavy metals is through phytoremediation, using plants to uptake soil contaminants. Popular species such as the brown mustard plant, *Brassica juncea* is often used in the phytoremediation process. The objective of this study is to determine if *Brassica juncea* can uptake large quantities of lead and arsenic found in NYC soils. In total 8 flower pots of contaminated soils were used, 4 that contain high levels of arsenic and 4 that continued high levels of lead. There was also a control group that consisted of 4 flower pots of "clean" soil, which was soil that did not contain lead or arsenic. The seeds of the *Brassica juncea* were grown in all these pots over a 5 month interval. An X-ray fluorescence gun was used to analyze the concentration in parts per million (ppm) for each soil sample, before and after the *Brassica juncea* seeds were planted. It was originally hypothesized that the *Brassica juncea* plants would be able to uptake large quantities of these heavy metals. However, this research study has shown that *Brassica juncea* plants were not able to achieve this goal.

Introduction

Soil is a vital component to living things. For instance, soil provides essential nutrients that helps us humans grow crops for food production and soil also plays as a habitat to many organisms (Petersen, 2019). However, with the rapid growth of industrialization and urbanization, pollutants such as heavy metals have made their place into soils. In which, humans can be exposed to these heavy metals through the crops that they eat, as the crops absorb the heavy metals from the soil (Egendorf, et al 2018).

Soils have been contaminated by heavy metal by numerous factors. This includes carbon emissions of cars, factories dumping their wastes, mine tailings, disposal of high metal wastes, and sewage sludge. Contamination of heavy metals in soils can have many adverse health effects. This includes how lead toxicity can cause organ damage because it can affect one's neurotransmitter levels (Bekash, 2019) and dysfunction of reproductive and cardiovascular systems (Kacholi and Sahu, 2018). As for arsenic, if it is consumed over a long period of time, it can cause skin pigmentation changes and even skin cancer (Arsenic). Exposure to heavy metals contaminated soils can be very serious and also more common than people think, which is why more needs to be done to make sure that the soil that we are using does not contain large concentrations of lead and arsenic.

This is where phytoremediation, an affordable method that uses plants to uptake pollutants, comes into play. However, not all plants can uptake heavy metals, usually hyperaccumulators can. Hyperaccumulators are able to uptake heavy metals because they can withstand the toxicity of the metals and one plant species that is considered to be a hyperaccumulator is the brown mustard plant *Brassica juncea* (Hyperaccumulator). Previous research has also shown this to be true. For example, researchers such as Satoru Ishikawa have mentioned that *Brassica juncea is a* suitable plant for phytoremediation for heavy metals such as cadmium (Ishikawa).

The purpose of this research study is to evaluate the effectiveness of *Brassica juncea* uptaking lead and arsenic from contaminated soil samples. Additionally, the findings of this research can help decide how useful phytoremediation is in terms of cleaning up soils and making it safe for crops to grow on them.

Materials

- Soil contaminated by lead and arsenic, from two gardening sites
- A bag of Miracle-Gro Premium Potting Mix (control group soil)
- 24 plastic bags
- A black marker
- 36 Brassica Juncea seeds
- 12 4.5 inch flowering pots
- XRF (X-ray fluorescence) gun

Methods

Soils Sample Sites

When gathering soil samples, make sure the area you are getting the soil from is known to be contaminated by arsenic and lead. You also have to have “clean” soil that is not contaminated by any of these heavy metals, as this will be your control group. In this experiment, soil samples were taken from the Sterling Community Garden of Brooklyn, New York and another NYC community garden located near a paint factory in Brooklyn, New York. The Sterling Community Garden is famously known for its dangerous levels of lead. For example, it was found that a sample of soil from this garden contained 1,251 parts per million of lead which is triple of the federal guideline of 400 parts per million (Buiso, 2019). All the lead samples came from this garden.

The second site that was used was a NYC community garden located near a paint factory in Brooklyn. Arsenic can be found in paint manufacturing wastes, and it was found that the soil in this garden was contaminated by high levels of arsenic, which is why all the arsenic samples came from this site. It is worth mentioning that, before soil samples were taken, permission from the New York City Department of Parks & Recreation was given. Lastly, the “clean” soil samples were bought from a local store and the brand that was used was Miracle-Gro Premium Potting Mix, and is known not to have high levels of toxic metals.

When gathering the soil samples from these sites and opening the Miracle-Gro Premium Potting Mix, the samples were placed into labeled plastic bags. With a black marker, the bags were labeled “clean #1” and “clean #2” for the control group samples, 4 of them were labeled as “lead” with a number from 1-4 and another 4 were labeled “arsenic” with a number from 1-4.

Then each of the bags were filled with the designated soil samples. The remaining of the plastic bags will be used in the Soil Testing section.

Soil/ Planting Preparation

Before placing the seeds into the pot, the X-ray fluorescence (XRF) gun was used to find the concentration of lead and arsenic for each sample. The XRF gun was placed on the surface of each plastic bag and then the trigger was pressed for a couple of seconds until the readings were displayed onto the screen. The readings gave the exact concentration of lead and arsenic present in each sample in parts per million (ppm) and these values were recorded into an excel file labeled as “readings before”.

When it came to assembling the flower pots, 4 of the pots were filled with the “clean” soil, another 4 of the pots were filled with lead samples, and the other 4 were filled with the arsenic samples. The flower pots were labeled the same way as the plastic bags.

After this was completed, three seeds were planted into each pot, the reason more than one seed was placed was because there might have been a chance one of the seeds may have not germinated, so placing extra can guaranteed that there would’ve been at least one plant per pot to work with. The pots were then all placed on a rooftop, which was a big open area, that recieved daily sunlight. The plants were also watered twice a week. They were then left to grow over a 5 month period, as this is the time it takes for the *Brassica juncea* to fully mature (Brassica juncea).

Soil Testing

After the plants were done growing for five months, each plant was taken out and the soil were placed into new bags labeled in a similar manner like the bags that were discussed in the Soil Sample Site section. Then, the bags were scanned by the XRF gun and the concentration of each sample was determined. The results were placed into another excel file labeled as "readings after". The average plant height from the lead, arsenic, and clean soil samples were also measured and compared to see if there was any relationship with the growth of the plant and the heavy metals present.

Results

Table 1: Lead XRF Readings Before Seed Planting

Sample ID	Pb (ppm)
Lead 1	1000
Lead 2	988
Lead 3	1200
Lead 4	880

Table 1. This table displays the results of the XRF testing on the soil for the lead samples before the *Brassica juncea* seeds were planted. The numbers indicate the concentration of lead in the soil samples using the units "parts per million".

Table 2: Arsenic XRF Readings Before Seed Planting

Sample ID	As (ppm)
Arsenic 1	400
Arsenic 2	555
Arsenic 3	433
Arsenic 4	525

Table 2. This table displays the results of the XRF testing on the soil for the arsenic samples before the *Brassica juncea* seeds were planted. The numbers indicate the concentration of arsenic in the soil samples using the units "parts per million".

Table 3: Lead XRF Readings After Seed Planting

Sample ID	Pb (ppm)
Lead 1	980
Lead 2	966
Lead 3	1160
Lead 4	845

Table 3. This table displays the results of the XRF testing on the soil for the lead samples after the *Brassica juncea* seeds were planted. The numbers indicate the concentration of arsenic in the soil samples using the units "parts per million". The average lead uptaken by the plants was calculated to be 29.25 ppm.

Table 4: Arsenic XRF Readings After Seed Planting

Sample ID	Pb (ppm)
Arsenic 1	340
Arsenic 2	535
Arsenic 3	400
Arsenic 4	480

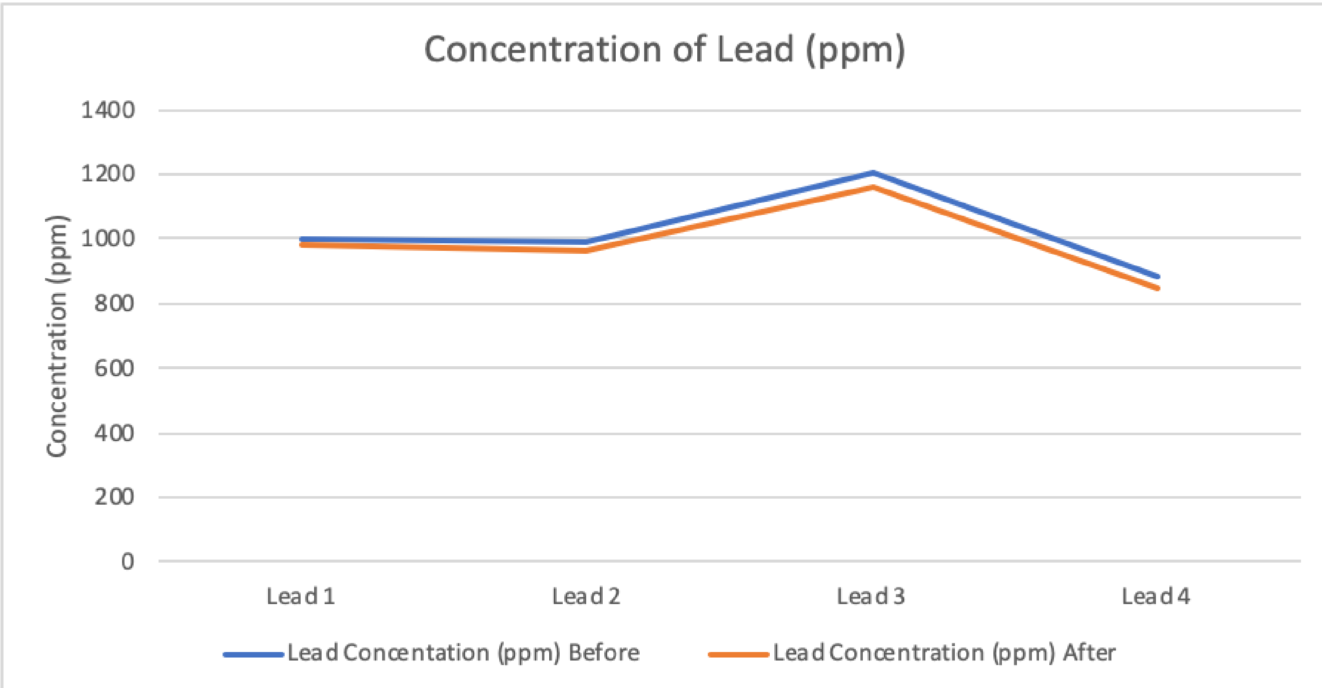
Table 4. This table displays the results of the XRF testing on the soil for the arsenic samples after the *Brassica Juncea* seeds were planted. The numbers indicate the concentration of arsenic in the soil samples using the units "parts per million". The average arsenic uptaken by the plants was calculated to be 29.50 ppm.

Table 5: Control Group

Sample ID	Pb Concentration (ppm)	As Concentration (ppm)
Clean Soil 1	0	0
Clean Soil 2	0	0
Clean Soil 3	0	0
Clean Soil 4	0	0

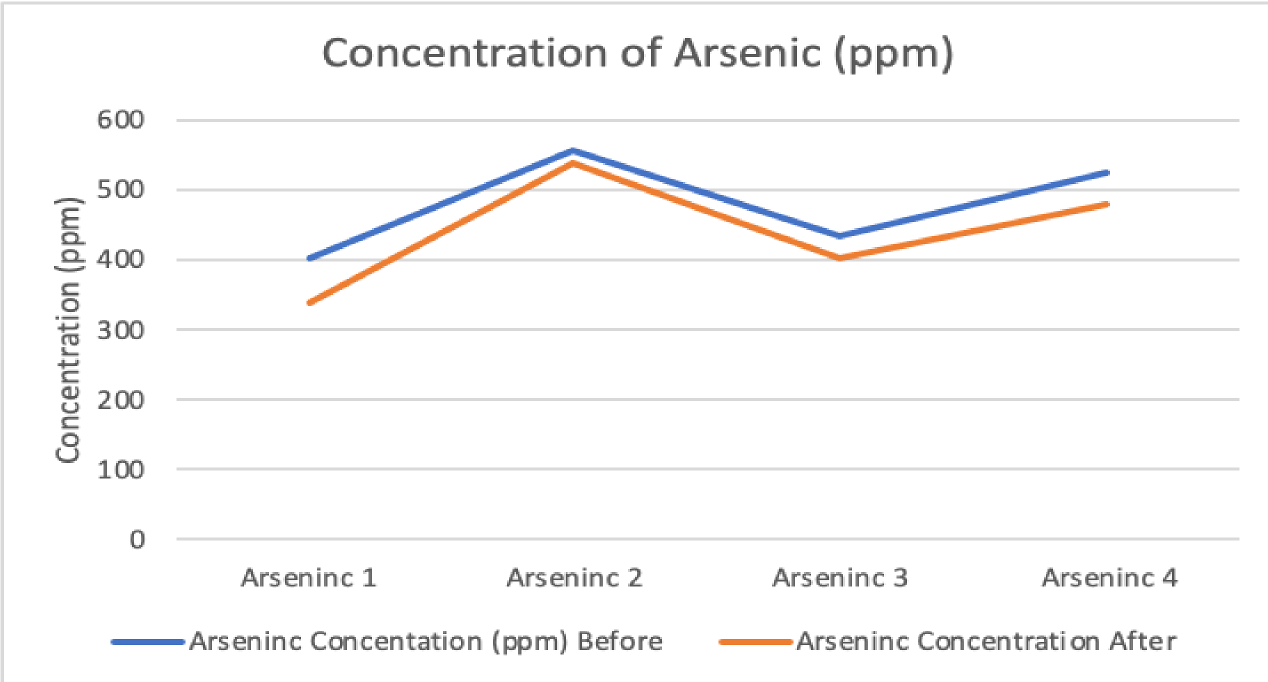
Table 5. This table displays the concentration of the clean soil samples, which had no arsenic and lead present in the samples. The numbers indicate the concentration of arsenic in the soil samples using the units "parts per million".

Graph 1:



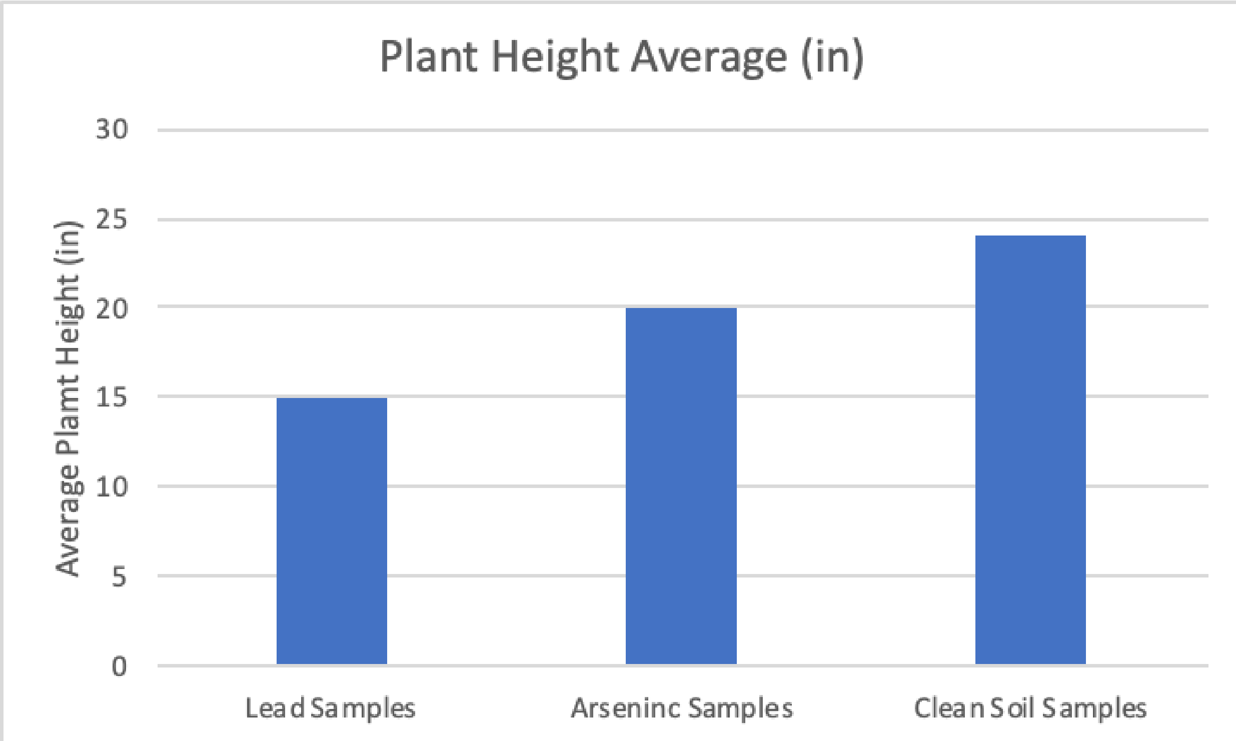
Graph 1. This graph compares the concentration of lead both before and after the *Brassica juncea* seeds were planted. As shown by how close the two lines are, the plants did not uptake much of the lead.

Graph 2:



Graph 2. This graph compares the concentration of arsenic both before and after the *Brassica juncea* seeds were planted. As shown by how close the two lines are, the plants did uptake more visible amounts than the lead samples (refer back to Graph 1).

Graph 3:



Graph 3. This graph compares the average plant height for all the soils samples of this experiment. As shown, the lead samples had the smallest average growth (15 inches) and the clean soil samples had the largest (24 inches), whereas the arsenic samples were between those lengths (20 inches).

Discussion

Although Brassica Juncea is known to be an effective plant for phytoremediation, it was not effective uptaking large quantities of lead and arsenic. When looking at **Graph 1**, it can be seen that the lines that represent the concentration of lead before and after the seeds were planted are very close together. This shows a visual representation that the plants did not take up much of the lead. If the *Brassica juncea* plant was effective at taking up large quantities of lead, the two lines would've been more sparse. However, when looking at **Graph 2**, the lines that represent the concentration of arsenic before and after were a bit more separated when compared to **Graph 1.** But this did not necessarily mean that a lot of the arsenic was taken up, as the average amount of arsenic taken up by the Brassica juncea was not high.

To determine the average amount of concentration taken by the Brassica juncea the difference of lead concentrations from Table 1 and Table 3 and the difference of arsenic concentration from Table 2 and Table 4 were taken. Then, those differences were added and divided by 4. It was found that the average for lead was 29.25 ppm and for arsenic it was 39.5 ppm. These values are not high but they do show that the Brassica juncea plants were able to uptake more arsenic for each given sample than for its lead samples. This can possibly mean that Brassica juncea can be more effective in uptaking arsenic than lead, but then again more research needs to be done on this finding. Moreover, in the future, people should allow the Brassica juncea to grow for more than five months because maybe by allowing the plant to grow for longer, different results can occur.

In addition, another component that was analyzed was the average growth of the plants. Although three seeds were planted in each flowering pot, it turned out that only one out of three seeds was fully able to germinate and grow for each sample. After the 5 month period, the plants were taken out from the flowering pots, and the lengths of the plants were measured from the stem to the tip of the plant. Then all the plant heights under the lead, arsenic, and clean soil category were added separately and divided by 4. It was found that the average plant growth for the lead samples was 15 in, for the arsenic samples it was 20 in, and for the clean soil samples it was 24 in, refer back to **Graph 3**. This shows that in this experiment, the soil contaminated by arsenic was a much more ideal environment than the soil contaminated by lead and can possibly indicate that the Brassica juncea plants have a higher tolerance for arsenic than lead, but more research needs to be done on this until this can be proven.

Conclusion

Making sure that the soil that is used to grow the crops that we eat is not contaminated by the heavy metals lead and arsenic is extremely important. This is because if people continue to eat the crops that are grown in heavy metal contaminated soil, they are indirectly consuming the heavy metals, which research shows has adverse health effects.

Although the Brassica juncea plants did not uptake large quantities of both lead and arsenic, the data does show that the plants were able to take in more arsenic for each given sample than for the lead samples. The data also showed that on average the Brassica juncea plants had more growth in the arsenic soils samples than in the lead soil samples. This can potentially mean that the Brassica juncea plants have a higher tolerance for arsenic than lead. This also opens a new research topic that should be studied because if this is true, farmers whose soil is mainly contaminated by arsenic and need small quantities of the arsenic to be taken out for the soil to be safe, they can use the Brassica juncea plants.

Nonetheless, one of the limitations of this research experiment was that only an XRF gun was used to determine the concentration of heavy metals. However, there are other more accurate methods to find these readings. This includes using an inductively coupled plasma mass spectrometry (ICP-MS) rather than just an XRF gun, or both can be used to see if there are any differences in results. By doing this, more precise results can be attained. All in all, this research helps build our understanding of phytoremediation as well as our understanding of the Brassica juncea's ability to uptake lead and arsenic from contaminated soils.

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Reflection

For this writing assignment, the genre was a scientific lab report. The purpose of a scientific lab report is to explain and showcase the process of a research experiment that was conducted. Lab reports usually follow a structure that usually comprises an abstract, introduction, materials/methods, procedure, results, discussion, conclusion, and a reference section. Since I followed the following conventions, I believe I was able to write an accurate lab report on the topic of my choosing, (Phytoremediation of Heavy Metal Contaminated Soils).

The media of this lab report was multimodal. At first, my group and I discussed what the topic will be about and orally described what information will go in which section, all which can be considered a media of oral communication. Then, we had to do an online version of our drafts for peer review on Blackboard as well as submit a digital copy on this platform as well, this is considered to be a digital medium. Since, this assignment consisted of two different media it is considered multimodal.

The purpose of my lab report was to showcase whether or not the brown mustard species Brassica juncea can uptake large quantities of lead and arsenic from contaminated soils through the process of phytoremediation. My hypothesis, what I thought was gonna happen, was that the Brassica juncea plants would be able to uptake large quantities of lead and arsenic because previous research has explained that Brassica juncea was an effective plant for phytoremediation for uptaking heavy metals like cadmium. However, the results of my research experiment educated people to understand that although Brassica juncea can uptake heavy metals it cannot uptake large quantities of lead and arsenic. In addition, another purpose of lab reports is to promote new research ideas. In my case, my research experiment promotes the idea of doing research to find out whether or not the Brassica juncea is able to grow more in soil contaminated in arsenic than lead.

The exigence of this lab report was to educate people that heavy metal soil contamination is a serious problem that more people need to be aware of. When we eat crops that are grown in soils, we don't really think about whether or not the soil that is being used to grow the crops is heavily contaminated by lead or arsenic. But, if we don't take precautions we can be eating crops that uptake the heavy metals present in the soils, which can lead us to face adverse health effects. This is why more research needs to be done to find cheap and effective methods to clean up heavy metal contaminated soils. In addition, this is also why my stance in my lab report was that more needs to be done to clean up soils that are used for agricultural purposes for human safety.

The audience for this lab report targets people who grow crops as well as scientists who are trying to learn more about phytoremediation using Brassica juncea. One of the sites I chose in this experiment was the Sterling Community Garden of Brooklyn, New York because many local people who live near the garden grow crops there and some don't even know how heavily contaminated the soil is with lead. But through this lab report they can get educated and may try to find plants, other than the Brassica juncea, to uptake the lead from their soil. Not only that, but previous research shows how Brassica juncea can uptake heavy metals like cadmium, this lab research can be useful to other researchers who may want to know if Brassica juncea can uptake large quantities of other heavy metals like lead and arsenic.

Lastly, with this assignment I have met quite a few of the course learning outcomes, which includes #2, 3, 4, 5, 7, and 8. I have outcome #2 by reviewing the comments my group members made on my paper during peer review and then fixing those errors to make my paper stronger. We also had to use a rubric and explain why we gave certain scores based on the rubric to our group members papers. By doing this I was able to enhance my strategies for editing because I knew what to look out for because the rubric explained how we would lose points. I met outcome #3 because I got to choose what my stance and purpose was for this lab report for me to reach my writing goal. My goal was to showcase how serious heavy metal soil contamination is and whether or not Brassica juncea can take large quantities of lead and arsenic, which was accomplished.

I met outcome #4 since my group and I collaborated on Blackboard to edit each other's papers and evaluate how well we did this assignment, so we can fix any problems we had in our lab reports. Not only that, but as mentioned before, this lab report was a multimodal media which helped me meet outcome #5. Furthermore, I met outcome #7 and 8 because I used online databases to find scholarly research papers and to help support my information and cited/utilized those information throughout my lab report in the APA format.