Analyzing the Effectiveness of Phytoremediation, with the *Brassica juncea* plant, in Extracting Heavy Metal Pollutants from Industrial Soils

Serly Tomas, Alina Shahin, Veronica Jaramillo Ph.D.

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Pasadena City College

Introduction

Urbanization and industry like mining and agriculture have contributed to higher heavy metal concentrations in soil. Although heavy metals occur naturally, these industrial activities have raised the concentrations of certain metals to dangerous levels which are toxic to plants and animals in high concentrations, as well as pose a danger to human health. Consumption of plants or animals containing accumulated amounts of heavy metals by humans can have long-term detrimental effects. Several techniques have been adopted to attempt to minimize the concentration of these heavy metals from soil, one of them being phytoremediated by plants, which is a cost-effective method to remove heavy metal contaminants from soil.

Brassica juncea, commonly known as the Indian Mustard Plant, is utilized in phytoextraction of heavy metals. The most common heavy metal pollutants include zinc, chromium, copper, and manganese. X-ray fluorescence (XRF) is used to detect the metal concentrations. This study aimed to determine the effectiveness of utilizing *Brassica juncea* for phytoremediation of heavy metals in experimentally polluted soils. A handheld XRF spectrometer was used to determine any changes in the metal concentrations.

Methodology

Five soil systems were set up using 3 x 4 square planting pots, each system had ten pots as shown in Figure 1.

- 1 system was the control, which was treated with distilled water. The 4 experimental systems were each treated with 30.00 ppm of $Zn(NO_3)_2$, $Mn(NO_3)_2$, $Cr(NO_3)_2$ and $Cu(NO_3)_2$.
- In each system, half of the pots were treated with 5.00 mL of the metal solution and the other half were treated with 10.00 mL of the metal solution.
- Ten Indian mustard planting seeds were placed in each slot and were watered with their designated solutions.
- Two soil samples were collected from each system, one from the 5.00mL treatment and one from the 10.00mL treatment.
- Soil samples were collected before planting, and then weekly after planting for four weeks.
- Soil samples were dried overnight at 105°C in a laboratory oven and then tested with the Bruker S1 TITAN Handheld XRF spectrometer.

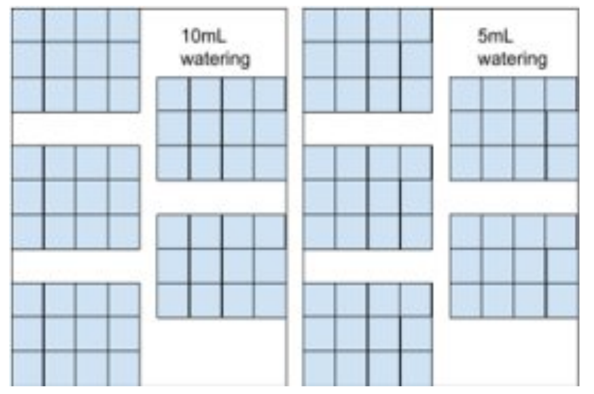


Figure 1: 3 x 4 square pots, each system having 10 large pots

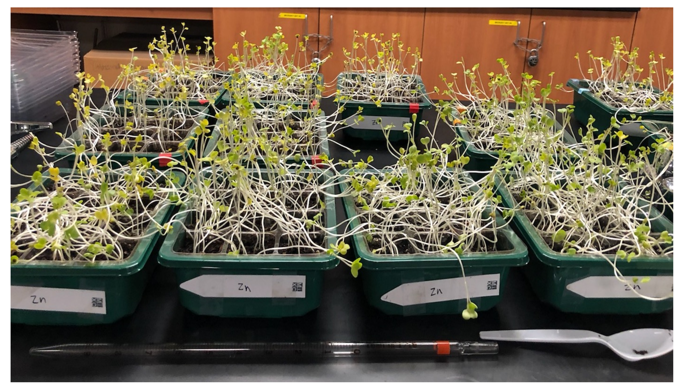


Figure 2: Experimental system with 30.00ppm $Zn(NO_3)_2$ solution treatment

Results

The amount (in mg) of each metal added to the soil samples was compared to the amount detected with the XRF as shown in Figures 3-6. The errors were determined from control soil system before planting.

- **Figure 3-** demonstrated that the increase in the detected Zn concentration varied directly with the addition of Zn through watering for both 5.00mL and 10.00mL treatments. The last soil sample was collected after a week of not watering at all; correspondingly, a decrease in the detected Zn concentration was found.
- **Figure 4-** demonstrated that the chromium detected (in ppm) increased with the first addition of Cr for both the soils treated with 5.00mL and 10.00mL. A slight decrease in the Cr was detected between the third and fourth data points of Cr in the 10.00mL treatment, and a decrease in the detected concentration of Cr between the second and third additions of the Cr in the 5.00mL treatment. Overall, there was a direct correlation between Cr detected and added with any decrease not significant.
- **Figure 5-** demonstrated a direct relationship between the amount of Cu added and the amount of Cu detected.
- **Figure 6-** demonstrated a direct correlation between the concentration of added Mn and the concentration of Mn detected for both 5.00mL and 10.00mL treatments; such that both are increasing. For the 10.00mL treatment, a slight decrease is shown between the addition of 2.1mg and 2.4 mg. For the final sampling, where soil was collected after a week of not watering, a decrease in the detected Mn concentration was seen for both 5.00mL and 10.00mL treatments.

Figure 3: Plot of Zn measured via XRF in ppm versus mg of Zn added

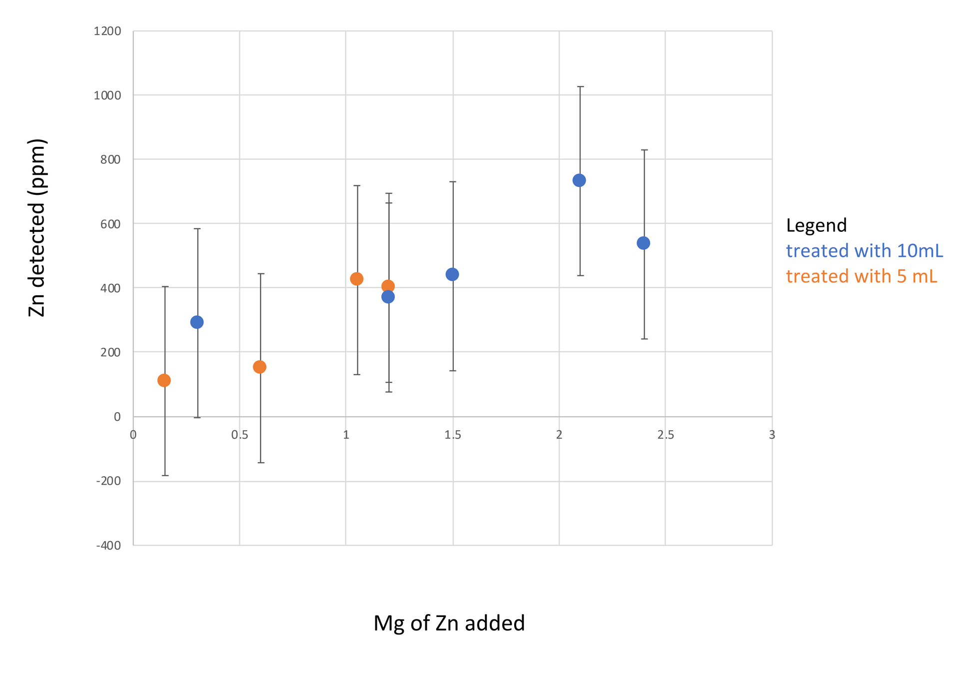


Figure 4: Plot of Cr measured via XRF in ppm versus mg of Cr added

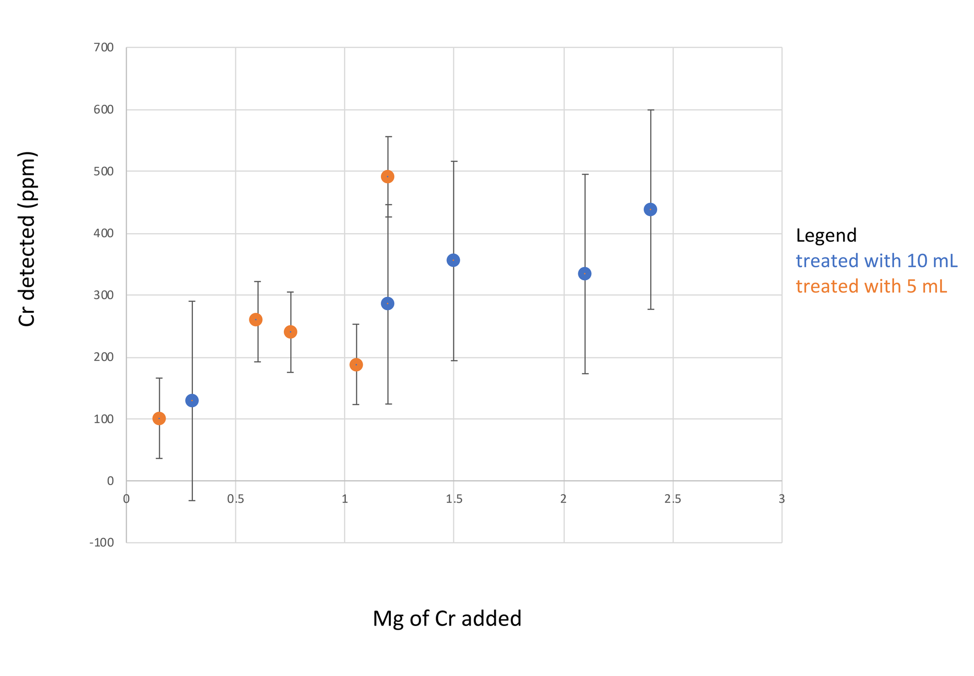


Figure 5: Plot of Cu measured via XRF in ppm versus mg of Cu added

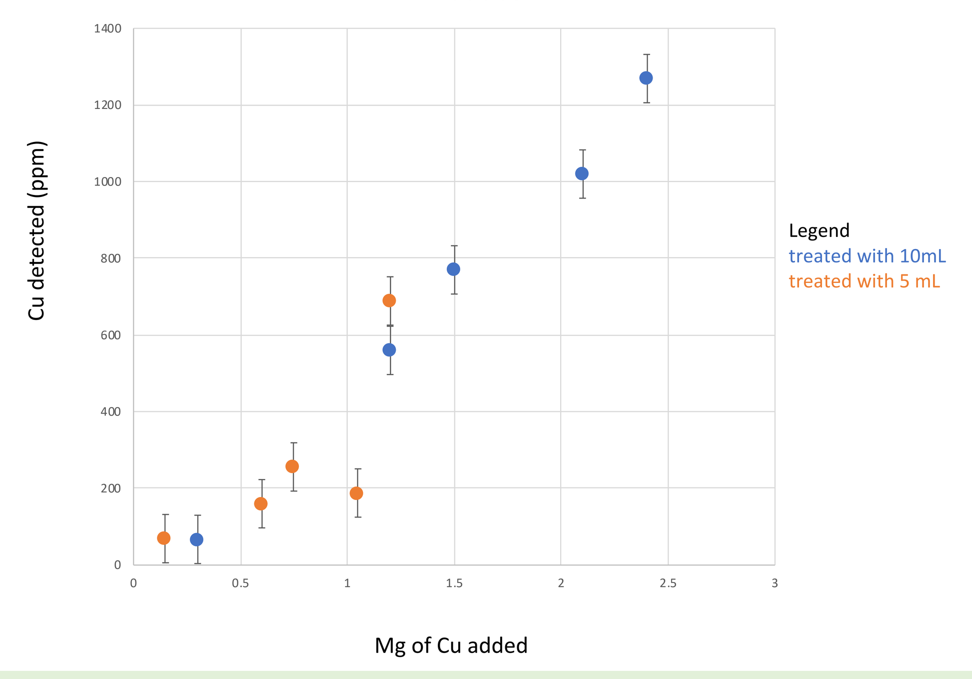
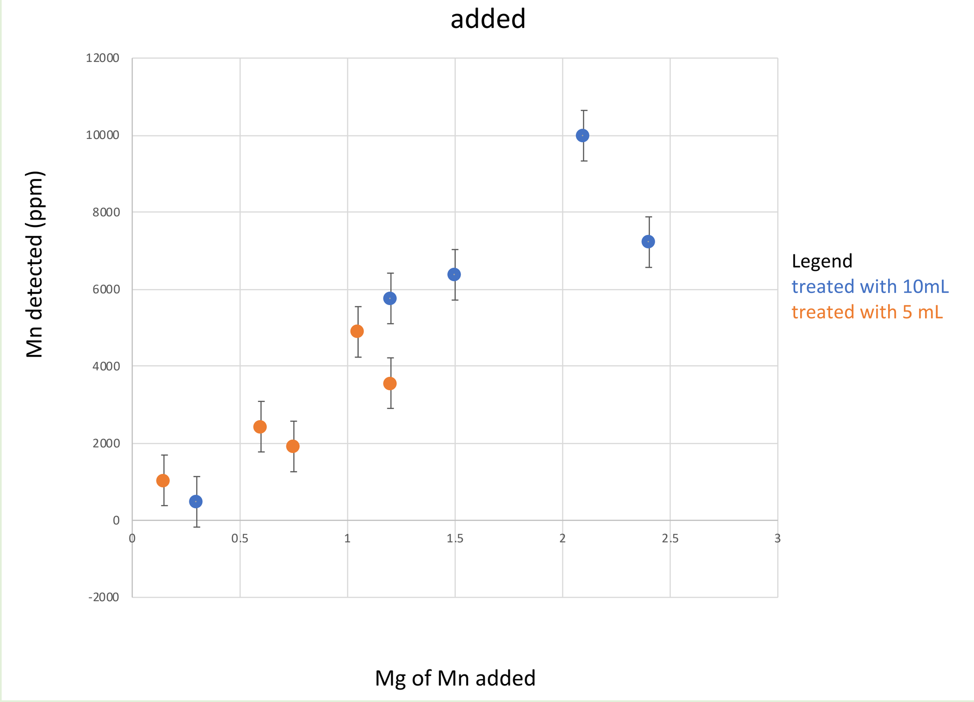


Figure 6: Plot of Mn measured via XRF in ppm versus mg of Mn added



Discussion

- In **Figure 3**, there is a direct correlation between the detected Zn concentration and the Zn added. The last data point for both 5 mL and 10 mL treatments display a sudden drop in the Zn detected after a week of no watering. This shows that the plants were able to extract metal from the soil more effectively when not being watered frequently.
- The decrease in detected Cr concentration was seen in both the 5mL and 10 mL treatments, between the addition of 0.6mg to 1.05mg for the 5mL and between the addition of 1.5 mg to 2.1mg for the 10mL treatment. These might be due to a systematic error in detection or the mixture having heterogeneous distribution. Other than that, the correlation between Cr added and detected is positive, which shows that the plants did not have any extraction effect.
- The direct relationship between the amount of Cu added and detected shown in **Figure 5** indicates that there was no effective phytoextraction by the plant. The Cu detected increases almost linearly with the Cu added.
- The direct correlation between the amount of Mn added and detected shown in **Figure 6** indicates that the plant wasn't effectively extracting the metal while being consistently watered. However, when the plants were not watered for a week, a significant amount of Mn was extracted as shown in the last data point for both the 5mL and 10mL treatments.
- Overall, *Brassica Juncea* was effective in extracting zinc and manganese from the experimental systems when there was no constant addition of those metals through watering. It was not effective in extracting of chromium and manganese, as the detected amounts continued to increase with the addition of those metals.

Future Direction

Although ineffective in the case of copper and chromium, further studies might be performed to discover which metals the *Brassica juncea* plant is able to absorb most efficiently. This study might be performed again, with more data collection performed each week and more time between watering. This will allow for greater analysis of the plant capabilities. With greater knowledge of its absorption capabilities, this plant might be used to clean polluted soils in the future.

Acknowledgements

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