Using Chelators to Enhance the Phytoremediation Utility of Broccoli, Mustard, and Thale Cress Plants

A plant-based approach to removing heavy metals from the environment

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ABSTRACT

Phytoremediation is a possible solution to purify soil contaminated with lead. Given their tolerance to lead, ease of growth, and low cost, *Brassica juncea* (mustard), *Brassica oleracea* (broccoli), and *Arabidopsis thaliana* (thale cress) are good candidates for phytoremediation. A method to enhance phytoremediation by the three plants is the chelation of lead prior to uptake. Penicillamine is a chelator commonly used to treat lead poisoning in humans. Additionally, the chemical 5-aminosalicylic acid has been shown to successfully chelate lead (II), among other metal ions. Utilizing the Advanced Photon Source (APS), we employed X-ray fluorescence (XRF) to reveal the amount of lead absorbed by *B. juncea, B. oleracea*, and *A. thaliana* in combination with several different chelators. By further analyzing this information, an optimal chelator for the phytoremediation of lead-contaminated soils could be determined. Certain chelators increased lead uptake in certain plant species tested during this experiment, with salicylic acid appearing to be the most effective.

EXPERIMENT OVERVIEW

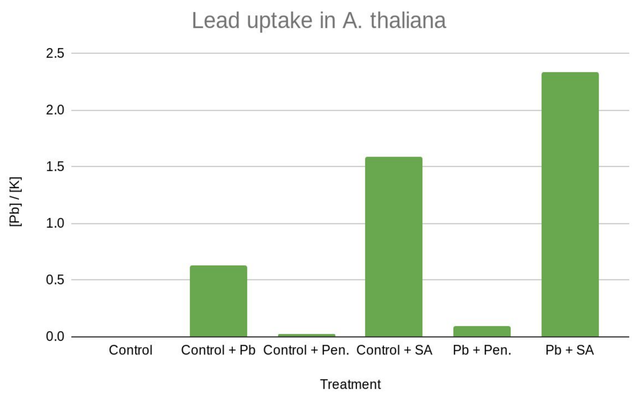
In this experiment, we tested lead absorption by *B. juncea*, *B. oleracea*, and *A. thaliana* when exposed to various chelators. We germinated multiple specimens of each plant species in a sterile medium infused with lead and chelators according to our control and experimental protocols. We used the Advanced Photon Source, which produces the high-energy X-ray beams necessary to quantify lead absorption in root tissue. This data was analyzed through XRF-Maps to determine which chelator was most effective at enhancing lead absorption.

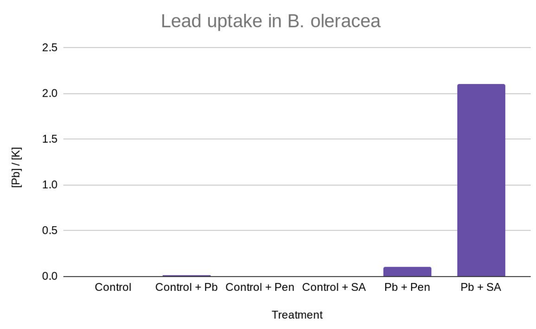
CONCLUSION

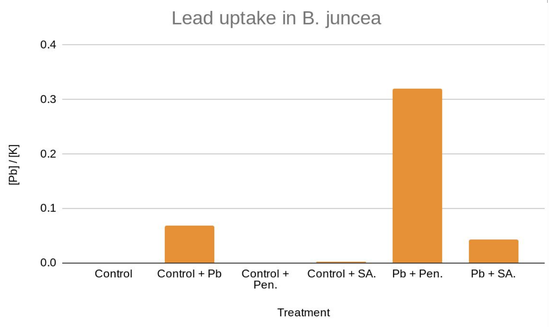
- The effectiveness of the chelator is dependent on the type of plant on which it is used.
- Penicillamine increased lead accumulation in *B. juncea* and decreased it in *A. thaliana*. The lead uptake in *B. oleracea* was not affected.
- 5-aminosalicylic acid increased lead accumulation in *A. thaliana* and *B. oleracea.* It had no significant effect in *B. juncea.*
- A full analysis of treatment with a third chelator, dimercaptosuccinic acid (succimer), was initiated but not completed due to time constraints.

DATA ANALYSIS

Lead uptake was quantified by dividing each root's background-adjusted lead concentration (μg/cm^2) by its potassium concentration (μg/cm^2) [1]. The potassium concentration served as a correlate for root thickness. The [Pb]/[K] value corresponding to *A. thaliana* with only 5-aminosalicylic acid (SA) appears to show a significant increase in adjusted lead concentration compared to the *A. thaliana* control. As no lead was added to this group, this result should be disregarded.







[1] Yu, H. (2023) ESRP-Analysis [Source Code]. https://github.com/HarryYu1/ESRP-Analysis

IMAGES

- Figure 1: *B. juncea* control
- Figure 2: *B. juncea* with lead
- Figure 3: *B. juncea* with lead and succimer
- Figure 4: *B. juncea* with lead and salicylic acid

LEGEND:
Calcium (Ca) → **Red**
Lead (Pb) → **Green**
Zinc (Zn) → **Blue**

Figure 1

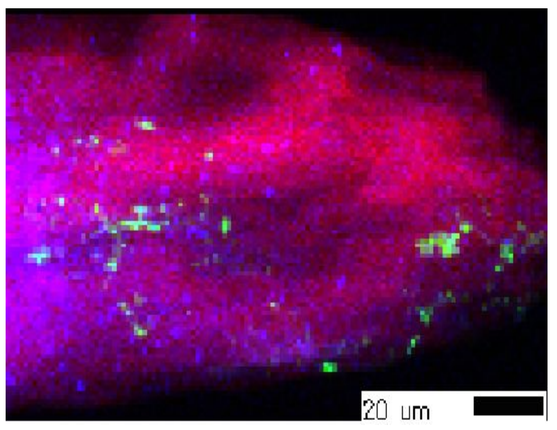


Figure 2

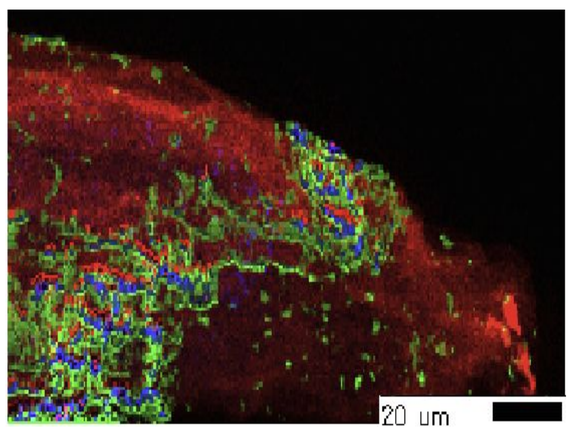


Figure 3

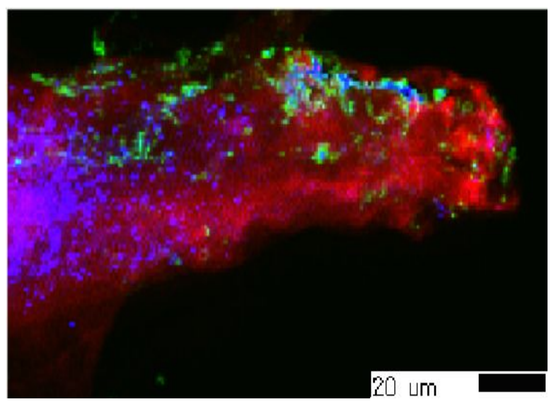
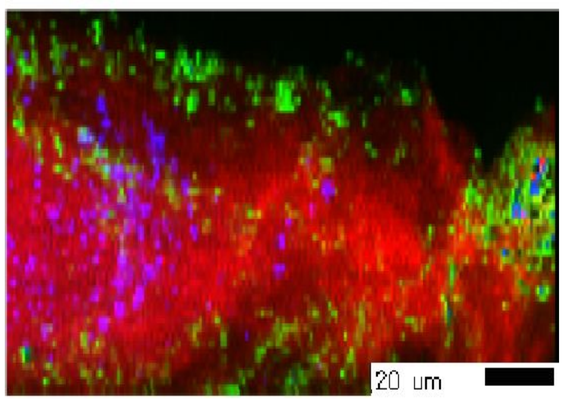


Figure 4



MOTIVATION

- Reducing the environmental presence of lead is necessary to prevent outbreaks of life-threatening illnesses.
  - Lead inhibits enzyme activity in cells and may result in memory loss, kidney and brain damage, and reduced fertility.
  - Gasoline, certain types of paint, car exhaust, and contaminated water are significant sources of lead poisoning.
- Phytoremediation involving chelators, which are chemical substances that bond to metal ions, is a possible approach to cleaning contaminated regions.

NEXT STEPS

- Further studies should be performed to confirm the observed effects of chelation on lead uptake in these plant species.
- A lower lead (II) nitrate treatment concentration should be used in future studies to prevent instrument saturation, which ruined several measurements.
- Ensuring that the seeds are free from lead prior to germination would improve the accuracy of future studies.

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