Assessing Arsenic: The Presence and Removal of A Heavy Metalloid Pollutant in New York Surface Waters Using Rhizofiltration

Manhattan College Jasper Summer Scholars Research Program

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Abstract

Heavy metals and metalloids can be toxic to humans and aquatic organisms in large doses and can have long term detrimental effects to the health of whole communities. If these substances get into our water they can cause many health issues such as cancer, organ damage, nervous system damage, and in extreme cases, death. An example of a toxic heavy metalloid that is found in groundwater and can find its way into surface water is Arsenic (As). Arsenic is often found in glyphosate-based herbicides, such as Roundup®. An innovative method to remove heavy metals is rhizofiltration, which an environmentally friendly way to absorb and remove heavy metal contaminants through root uptake. When compared to other methods, Rhizofiltration is a low-cost alternative to efficiently separate heavy metals and toxins from water. Certain plants, called hyperaccumulators, are especially good at absorbing these metals through their roots and concentrating high levels of metals in their tissues. The objective of this work is to study the potential for two hyperaccumulators (Virginia Rye and Indian Mustard Seed) to remove arsenic from surface waters.

Study Sites

Two Sites were selected for water sampling: Van Cortlandt Lake (VCL) and Tibbett's Brook (TB). These specific locations were chosen due to their close proximity to golf courses, which are treated with herbicides that potentially contain arsenic. Arsenic can enter these surface water sources through runoff from the golf course, as well as urban runoff from nearby highways (I-87).

Figure 1: Van Cortlandt Lake

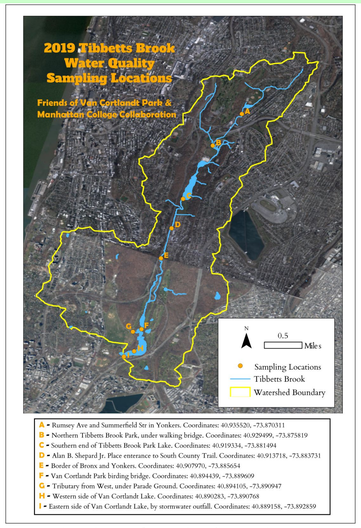


Figure 2: Map of Water Sampling Locations

Methods and Materials

Materials	Usage
Indian Mustard/Virginia Rye plants	used to remove arsenic from water in Rhizofiltration
Rockwool cubes	soil substitute for germination of seedlings
Grow lamp	provides artificial sunlight to plants indoors
Van Cortlandt Lake/Tibbetts Brook water samples	tested for concentration of arsenic and used in Rhizofiltration
Thermo Scientific pH meters	used to measure pH
Handheld EC probe	measures electrical conductivity
Turbidimeter	measures turbidity
Nitrate/Phosphorus Hach test tube kits and DR2800 spectrophotometer	measures nutrients in sample
Vacuum filtration manifold/filter cups	used for calculating suspended solids, dissolved solids and total solids
Flame AAS	Detects the presence of arsenic (ranging from 0-500 ppb)
Water baths	used to maintain constant temperature and water flow in Rhizofiltration

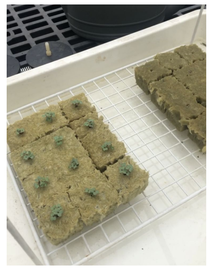


Figure 3: Germination Setup (Manhattan College Leo Greenhouse)

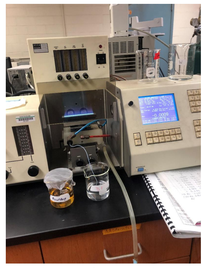


Figure 4: Flame Atomic Absorption Spectrometer

Figure 5: Vacuum filtration manifold for total suspended solids analysis.

Water Quality

pH	
Sample	Average pH
VCL	7.17
TB	7.01

Conductivity	
Sample	Average Conductivity (uS)
VCL	700.00
TB	883.33

Nutrients		
Sample	Nitrate (mg/L)	Phosphorus (mg/L)
VCL	1.03	0.375
TB	1.51	0.845

Total Dissolved Solids (TDS)	
Sample	Mass of Solids (mg/L)
VCL	0.789
TB	0.535

Total Suspended Solids (TSS)	
Sample	Mass of Solids (mg/L)
VCL	12.5
TB	9.55

Turbidity	
Sample	Average Turbidity
VCL	6.41
TB	5.18

Total Solids (TS)	
Sample	Mass of Solids (TSS+TDS) (mg/L)
VCL	13.289
TB	10.085

- High total nutrients, primarily nitrate and phosphorus, often lead to eutrophication (significant algal growth) in surface waters. Algae feed on these nutrients and spread.
- Turbidity is a measure of how clear/cloudy water is and is a good indicator of the amount of solids in the water. Both samples had relatively low turbidity.
- Conductivity measures water's ability to conduct electricity and can help determine water's salinity and what minerals or contaminants are in the water.

Experimental Conditions

- Two trials of Rhizofiltration were conducted, one with Van Cortlandt Lake water and another with Tibbetts Brook water.
- Each trial consisted of the use of one large water bath (~6000-9000mL) and a small one (~3000-4500mL).
- The small bath was used for Virginia Rye plants and the large bath for Indian Mustard.
- Solid sodium arsenate (As) was measured out and put in each bath so that the initial concentration of Arsenic in each was 10 mg/L. This was done to represent a spike.
- Each water bath remained at about 25°C for the entirety of the trials, and the large bath was continuously circulating it's water.

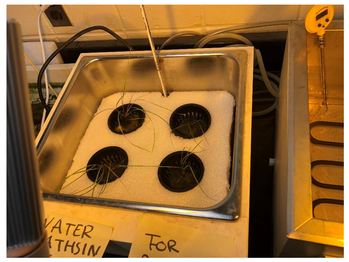
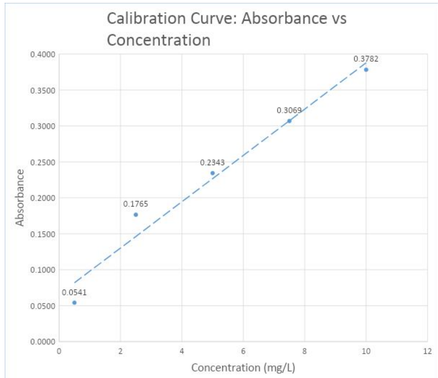


Figure 6: Small Water Bath containing Virginia Rye plants

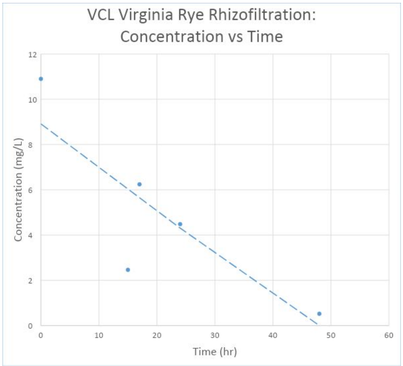
Figure 7: Large Water Bath containing Indian Mustard plants

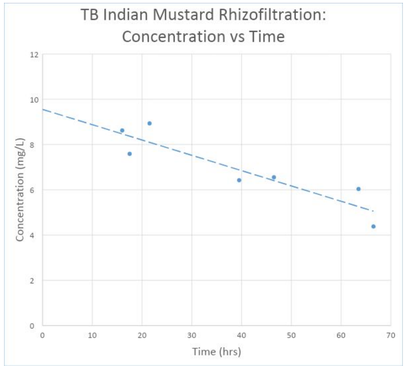
Calibration Curve

A machine called the Flame Atomic Absorption Spectrometer (Flame AAS) was used to read absorbance of Arsenic in filtered lake water samples, rhizofiltration samples, and Roundup herbicide. In order to calculate the concentration of Arsenic in these samples from their absorbance, multiple "standard" solutions (of known concentrations of Arsenic) were prepared. These standards were then used to make a calibration curve displaying Absorbance vs Concentration.



Rhizofiltration





Both trials consisted of the two water baths, one filled with Indian Mustard plants and another with Virginia Rye. Four sets of final data were expected, however two of these sets were inconclusive. This could be due to technical issues with the Flame AAS, human error or an abundance of algae on the roots. Future research can determine the change in concentration for these data sets.

Algal Growth

- The Virginia Rye and Indian Mustard were grown under two different conditions: Manhattan College Greenhouse (Figure 3, 9) and MC Environmental Lab (grow lamp) (Figures 6, 7).
- Less than a month after germination, algal growth was observed on the roots of those grown in the greenhouse (Figures 8, 9, 10).
- Future work will assess any differences in absorption between the roots with algal growth and those without algal growth.

Figure 8: Algae growth in container

Figure 9: Algae growth on the plants' roots

Figure 10: Algae covered roots vs uncovered roots

Conclusion

- Water from both Van Cortlandt Lake and Tibbetts Brook was placed in water baths and spiked to have an initial concentration of 10 mg/L. Samples were then collected and tested from both baths, and results were plotted to show how the plants' roots could uptake the contaminant, significantly reducing its concentration in water.
- More research would have to be done to determine what other plants could be used and how much they would be able to remove, but these results suggest that rhizofiltration would be a cheap and viable way to remove heavy metal and metalloid contaminants from surface waters.
- The use of local plants, Virginia Rye and Indian Mustard, shows that this can be done without introducing any foreign species into the ecosystem.

Acknowledgements

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