Izza Malik and Candace Arneaud

The Effect of Aster amellus and Carex morrawii on the Absorption of Metals in the Groundwater

Abstract

The accumulation of heavy metals is recorded yearly along the coast of Long Island to ascertain any potential health concerns. One way to address the issue of heavy metal pollution is through phytoremediation. Phytoremediation utilizes either terrestrial or aquatic green plants to remove, contain, inactivate, or degrade environmental pollutants. The purpose of the investigation was to determine whether terrestrial plants Aster *amellus* (Aster) and *Carex x Morrowii* (Japanese Sedge) could be possible phytoremediators. These plants were chosen because plants in their families have shown signs of phytoremediation due to their expression of genes such as metal chelator, metal transporter, metallothionein (MT), and phytochelatin (PC). The plants were tested for being an adequate phytoremediator based off whether they could absorb levels of arsenic, chromium, barium, lead, silver, mercury, selenium, and cadmium, which were administered to the plants through the soil prior to experimentation. The concentration of heavy metals was tested each week for six weeks using the Bruker S1 Titan XRF spectrometer. The soil and parts of the plant were tested twice a week, to determine any uptake of the metal solution. Statistical tests on the X-ray sample data and the Bioconcentration Factor and Accumulation Factor were evaluated. *Aster amellus* illustrated the most success after testing. The bioconcentration factor of barium, arsenic, chromium, and lead were significant enough to label *Aster amellus* a phytoremediator. One the other hand, *Carex morrowii.* lacked evidence to be considered a successful phytoremediator.

Introduction

The concentration of heavy metals on Long Island has been gradually increasing between 2000 and 2018 (LISS, 2019). The contaminated groundwater results in thousands of people drinking metal filled water. The concentration of zinc, mercury, and copper have increased the most over the last 18 years. The consumption of such contaminated water results in serious health problems. Heavy metals are non-biodegradable which contributes to bone defects, respiratory problems, as well as decentration of one's neurological capabilities. (Status and Trends: LISS Environmental Indicator 2019) Not only does it pose a large threat to human health; the accumulation of metals endangers ecosystems. Many of the plants in impacted areas die and those that survive cause the animals relying on them for food to become sick. The rise in heavy metal accumulation results in contaminated groundwater which leads the consumption of unsafe drinking water.

The most common heavy metal removal technique is excavation. Excavating consist of tearing up the ground to remove the contaminated soil. Although effective the extensive process can cost up to \$400 per cubic meter. The process takes numerous hours of labor and disrupts the ecosystem of the effective area. An alternative to the difficult process in Phytoremediation. The technique has increased in popularity and has proved to be a cost-effective alternative to restoring contaminated soil to its "pure" form. Phytoremediation uses terrestrial or aquatic green plants, to remove, contain, inactivate, or degrade harmful environmental pollutants (Vassilev et al., 2004). Plants absorb metals and store them in their aerial shoots as they do for water and nutrients. An increasing number of cost-effective phytoremediation techniques are being researched to remove metals from both the soil and ground water. One technique within phytoremediation is phytoextraction. Phytoextraction is the process in which contaminants are absorbed and accumulated into the roots, and are precipitated into the rhizosphere (Bolan et al., 2011). Unlike excavation, this technique cost only $40 per cubic meter and does not disrupt ecosystems as severely as excavation. (Schnoor, 1997)

Perennial plants have long, fibrous roots that enable them to be viable candidates for phytoremediation. For phytoremediation to occur, direct contact must be seen between the roots and the contaminated area. Also, these fibrous root span out from the main root allowing it to cover a large surface area. This is beneficial not only for phytoremediation but also for sustaining plant health during uptake. It gives the plant a stable foundation. Along with the fibrous roots, genes such as metal chelator, metal transporter, metallothionein (MT), and phytochelatin (PC) are expressed in some of the plants.(Eapen et. Al, 2005). These aid in up taking metals into the roots and leaves of the plant.

Procedure

Aster and Japanese Sedge were obtained at their optimal height and flowering capacity. The plants were placed in large plastic pots, afterwards. Each pot was filled with soil derived from a fertile planting area and contained a 3 in. Well for the plant to be placed in. Then, using a small pipette, six indents were made into the soil of varying depths.

The metals that were placed in the plants was from a solution containing 100ppm arsenic, 100ppm chromium, 10ppm silver, 50ppm barium, 100ppm lead, 50ppm cadmium, 50 ppm selenium, and 20ppm mercury. Six holes at varying depths were inserted into the pot of the plant, for heavy metal saturation. The holes were made at inconsistent heights (1.5in -2in) to symbolize the variability of an ecosystem and how nutrients and water are absorbed at different levels throughout the plant. The heavy metal solution saturated into the plant was pre-made and contained varying levels of metals common to marine ecosystems. 500 microliters of metal solution was injected into each of the 6 indents made around the area of the plant. Then, the plant proceeded to be watered with 50 ml of ionized water.

Each week, the plants would be examined under a light microscope to examine the health of the leaves from different areas of the plant. Then, a portion of the leaf from each plant, from both the proximal and distal sides, were tested for metal concentration using a X-Ray Fluorescence machine. Specifically, the Bruker S1 Titan XRF machine was used. The XRF device was calibrated with the original concentrations of all metals contained in the original solution. The subject being tested would be placed in a plastic container and protected in saran wrap. The machine is then connected to a computer in order to connect and save future results. The XRF device takes approximately 80 seconds to run a cycle and process results per sample. Furthermore, in addition to the leaves being tested, two regions of the soil closer to the base of the plant, was tested for metal concentration. Each plant was tested in this manner, for a total of 4 samples run per plant per week. The plants were x-rayed for the entire duration of the experimental period.

Results and Conclusion

Table 1. The average concentration of arsenic, chromium, silver, barium, lead, cadmium, selenium, and mercury in Aster soil over 6 weeks

Week	Average Metal Concentration(ppm)							
	As	Cr	Ag	Ba	Pb	Cd	Se	Hg
1	0.70	13.00	0.00	32.91	1.10	0.00	0.00	0.00
2	0.60	13.65	0.00	30.75	0.85	0.00	0.00	0.00
3	0.00	9.85	0.00	26.45	0.80	0.00	0.00	0.00
4	0.20	9.10	0.00	22.10	0.60	0.00	0.00	0.00
5	0.00	6.95	0.00	17.35	0.70	0.00	0.30	0.00
6	0.22	6.30	0.00	10.20	0.95	0.00	0.00	0.00
Standard Deviation	0.26	3.36	0.00	7.50	0.36	0.00	0.14	0.00
Percent Change	-68.57	-51.54	0.00	-69.01	-13.64	0.00	0.00	0.00

Table 2. The average concentration of arsenic, chromium, silver, barium, lead, cadmium, selenium, and mercury in Aster plant over 6 weeks

Week	Average Metal Concentration(ppm)							
	As	Cr	Ag	Ba	Pb	Cd	Se	Hg
1	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00
2	0.00	8.00	0.02	8.30	0.34	0.00	0.30	0.00
3	0.60	8.85	0.00	18.15	1.80	0.00	0.00	0.00
4	0.35	9.75	0.00	23.60	1.50	0.00	0.20	0.00
5	0.87	8.60	0.01	27.88	2.85	0.00	0.50	0.00
6	0.81	10.50	0.05	30.80	2.30	0.00	0.42	0.00
Standard Deviation	0.46	3.25	0.04	10.64	1.16	0.00	0.18	0.00
Percent Change	-	-	-	-	-	-	110	-

Table 3. The average concentration of arsenic, chromium, silver, barium, lead, cadmium, selenium, and mercury in Japanese Sedge plant over 6 weeks

Week	Average Metal Concentration(ppm)							
	As	Cr	Ag	Ba	Pb	Cd	Se	Hg
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00
3	0.30	6.60	0.00	0.00	1.20	0.00	0.20	0.00
4	0.30	3.20	0.00	0.00	0.11	0.00	0.01	0.00
5	0.15	5.73	0.00	0.00	0.05	0.00	0.00	0.00
6	0.15	7.75	0.00	1.40	0.00	0.00	0.00	0.00
Standard Deviation	0.09	1.74	0.00	0.40	0.57	0.00	0.10	0.00
Percent Change	-	-	-	-	-	-	-	-

Table 4. The average concentration of arsenic, chromium, silver, barium, lead, cadmium, selenium, and mercury in Japanese Sedge soil over 6 weeks

Week	Average Metal Concentration(ppm)							
	As	Cr	Ag	Ba	Pb	Cd	Se	Hg
1	0.00	11.30	0.00	8.40	0.75	0.00	0.00	1.70
2	0.13	8.15	0.00	0.60	0.60	0.00	0.00	0.00
3	0.40	7.30	0.00	0.60	0.60	1.50	0.00	0.00
4	0.00	7.85	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	7.30	0.00	0.00	0.00	0.19	0.00	1.30
6	0.00	7.90	0.00	0.00	0.00	0.00	0.02	0.00
Standacrd Deviation	0.19	1.89	0.00	1.90	0.15	0.93	0.01	0.59
Percente Change	-	-30.09	-	-100.00	-100.00	-	-	-100.00

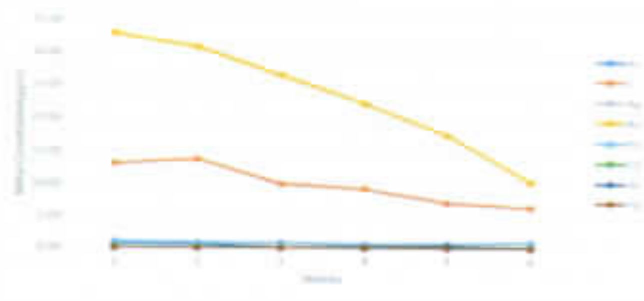

Figure 9. The average concentration of arsenic, chromium, silver, barium, lead, cadmium, selenium, and mercury in Aster soil over 6 weeks

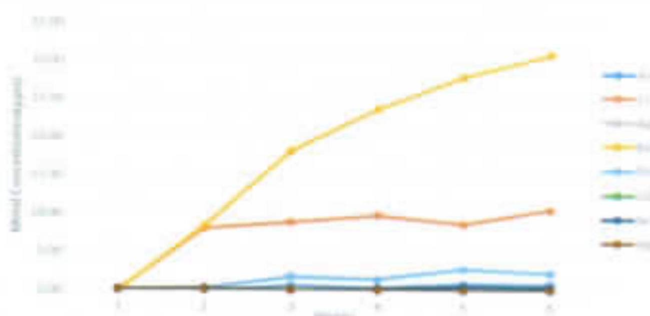

Figure 10. The average concentration of arsenic, chromium, silver, barium, lead, cadmium, selenium, and mercury in Aster plant over 6 weeks

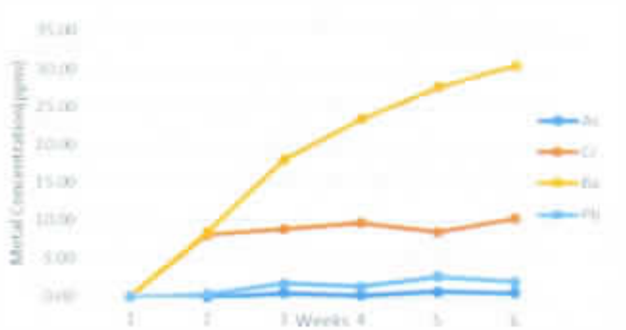

Figure 11. The average concentration of arsenic, chromium, barium, and lead in Aster plant over 6 weeks

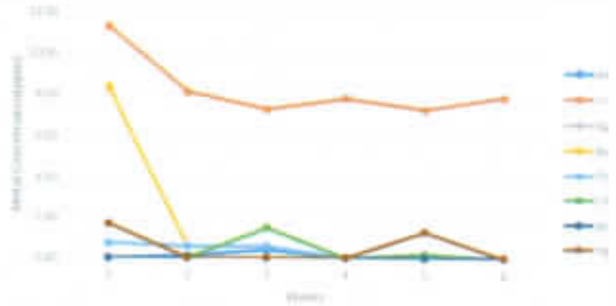

Figure 14. The average concentration of arsenic, chromium, silver, barium, lead, cadmium, selenium, and mercury in Japanese Sedge soil over 6 weeks

Figure 15. The average concentration of arsenic, chromium, silver, barium, lead, cadmium, selenium, and mercury in Japanese Sedge plant over 6 weeks

Figure 16. The average concentration of arsenic, chromium, barium, and lead, in Japanese Sedge plant over 6 weeks

Table 5. The final concentration of arsenic, chromium, silver, barium, lead, cadmium, selenium, and mercury in ppm in the soil and plant of Aster.

Metals	As	Cr	Ag	Ba	Pb	Cd	Se	Hg
Final Results of plant(ppm)	0.81	10.50	0.05	30.80	2.30	0.00	0.42	0.00
Final Results of Soil(ppm)	0.22	6.30	0.00	10.20	0.95	0.00	0.00	0.00
Bioconecentaion Factor	3.73	1.67	-	3.02	2.11	-	-	-
Accumulation Factor	372.73	166.67	-	301.96	210.53	-	-	-

Table 6. The final concentration of arsenic, chromium, silver, barium, lead, cadmium, selenium, and mercury in ppm in the soil and plant of Japanese Sedge.

Metals	As	Cr	Ag	Ba	Pb	Cd	Se	Hg
Final Results of plant(ppm)	0.15	7.75	0.00	1.40	0.00	0.00	0.00	0.00
Final Results of Soil(ppm)	0.00	7.90	0.00	0.00	0.00	0.00	0.02	0.00
Bioconecentaion Factor	-	0.98	-	-	-	-	0.00	-
Accumulation Factor	-	98.10	-	-	-	-	0.00	-

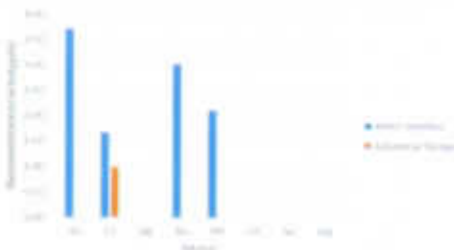

Figure 19. Bioconcentration factor comparison of Japanese Sedge and *Aster amellus*

Through the collection and evaluation of data, the investigation suggests that *Aster amellus* has a greater chance of being a suitable phytoremediator. When evaluating the data of *Aster amellus* an upward trend is seen by barium, chromium, arsenic, and lead in the plant. Barium and chromium have the greatest increase in concentration thus meaning that those metals are most easily absorbed by *Aster amellus.* A similar downward trend is seen by barium in the soil further supports the capabilities of *Aster amellus*. Additionally, the accumulation factor of 301.96%, signifies that most of the barium was absorbed. Similarly, arsenic, chromium, and lead have accumulation factors greater than 100 which suggest *Aster amellus* was effective in absorbing those metals. This is further supported by the decrease in soil contamination. The evaluation of metal concentrations suggests that *Aster amellus* is a sufficient phytoremeditator.

Carex morrowii shows promise of phytoremediation. The concentration changes seen in Figure 14 represent a decrease in the soil concentrations of chromium, barium, mercury, and lead. Although the percent change of these metals provided sufficient results, there accumulation factor is poor. Only the statistical analysis of chromium was produced, but it is below 100. Although it wasn't a strong phytoremediator, there was little visible change in the plant's health.

Overall, *Aster amellus* was a stronger phytoremediator. The bioconcentration factors of barium, chromium, lead, and arsenic for *Aster amellus* are greater than 1 meaning the plant absorbed an efficient amount of metals to be a phytoremediator. *Carex morrowii* is not a strong phytoremediator of the tested metals as seen in the comparison of bioconcentration factors seen is Figure 5. The line graph illustrates the significant difference between the two plants as well as the variability through the range. The number of samples taken from the plant and soil cannot fully represent the total concentration of the plant. Although this limits the data, more than 2 samples of plant shoots or soil could have caused great damage to the plant, invalidating the experiment. If the soil was dug up more than it was to obtain the samples there could have been damage to the roots thus weakening its ability to remediate and well as its ability to remain stable. The same hold true for the plant. If more than 2 samples were taken from the plants, there wouldn't be much of the plant to test in the later days because it would have been used up too quickly.

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