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Use of Aquatic Plants to Treat Waste Water in Developing Countries

Abstract

In developing countries, a cheap and efficient means of treating waste water is needed. Aquatic plants that can absorb heavy metals are in integral part of this process. For this reason, a series of three plants was studied to find their capacity to absorb heavy metals. Water Lettuce (*Pistia stratiotes*), Creeping Primrose (*Ludwigia palustrus*), and Yellow Lily (*Nymphaea Mexicana*) were all subjected to Iron, Lead, and Nickel contamination. The plants were damaged by the contamination, but they continued to absorb heavy metals. While inaccuracies in the Atomic Absorption Spectrometer made testing for Nickel impossible, the plants were shown to absorb Iron and Lead readily. The levels of Iron in the water were brought down to 6 ppm or less, and the concentration of Lead was brought down to nearly 0 ppm.

Introduction

Many residents of developing countries do not have access to clean drinking water. Because of the limited access to electricity, any solution for the treatment of waste water must be energy efficient. This constraint led to the use of a series of ponds that each do different filtering tasks to treat waste water. One of these ponds typically contains aquatic plants that are used to remove heavy metals.[i] Currently, Water Hyacinth and Duckweed are proven to be useful in removing metals[ii], but they are not readily available in all developing countries.

It is highly probable that other aquatic plants can absorb heavy metals as readily as Water Hyacinth and Duckweed. The purpose of this study is to find other aquatic plants that will absorb heavy metal readily so that they too can be used to effectively treat waste water in developing countries. This may also push further research beyond the scope of this study to be done to illuminate more possibilities for uses of aquatic plants in waste water treatment.

Materials and Methods

A set of three plants were tested for heavy metal absorption in this study: Water Lettuce (*Pistia stratiotes*), Creeping Primrose (*Ludwigia palustrus*), and Yellow Lily (*Nymphaea Mexicana*). These plants were chosen based on their absorption of heavy metals in studies done on the levels of heavy metals in various rivers.[iii] A series of 1-gallon polypropelene tanks were set up, each containing deionized water and plant food (Hoagland's No. 2 Basal Salt). The plant were grown in this medium for a week to get them established before the plants were subjected to the metals.

The 1-gallon tanks were then emptied out, cleaned thoroughly, and each tank was filled with 5 L of deionized water. The metal content of the plant food was analyzed using Atomic Absorption Spectroscopy (AA), and was found to contain 2 ppm Iron, negligible amounts of Lead, and no Nickel. The following amounts of plant food and heavy metals were added to the tanks.

Tank	Grams Basal Salt	Grams Ferric Nitrate	Initial concentration
Water Lettuce 1	2.0019 ± .0003	1.0503 ± .0003	12.80 ppm
Water Lettuce 2	2.0093 ± .0003	1.0492 ± .0003	13.50 ppm
Creeping Primrose 1	2.0171 ± .0003	1.0504 ± .0003	19.30 ppm
Creeping Primrose 2	2.0075 ± .0003	1.0503 ± .0003	23.55 ppm
Yellow Lily 1	2.0073 ± .0003	1.0518 ± .0003	22.75 ppm
Yellow Lily 2	1.9183 ± .0003	1.0504 ± .0003	22.25 ppm

Table 1: Shows the grams of plant food and iron that were put in each tank. Note that in this case the amount of plant food used was very important as the 2 ppm of Iron in the plant food was accounted for. Also note that the error presented in the chart is only the error attributed to the scale, as the error caused by precipitation of metals and loss to to transportation of powders is unknown.

Tank	Grams Basal Salt	Grams Lead (II) Nitrate	Initial concentration
Water Lettuce 1	2.0002 ± .0003	0.0088 ± .0003	0.1156 ppm
Water Lettuce 2	2.0011 ± .0003	0.0112 ± .0003	0.1006 ppm
Creeping Primrose 1	1.9755 ± .0003	0.0103 ± .0003	0.1098 ppm
Creeping Primrose 2	1.9860 ± .0003	0.0096 ± .0003	0.0988 ppm
Yellow Lily 1	1.8887 ± .0003	0.0082 ± .0003	0.1050 ppm
Yellow Lily 2	1.9333 ± .0003	0.0100 ± .0003	0.0741 ppm

Table 2: Shows the grams of plant food and Lead that were put in each tank. Note that the amount of plant food in each tank was not important to the concentration of lead since the amount of lead in the plant food was negligible. Also note that the error presented in the chart is only the error attributed to the scale, as the error caused by precipitation of metals and loss to to transportation of powders is unknown.

Tank	Grams Basal Salt	Grams Nickelous Nitrate	Initial concentration
Water Lettuce 1	0.1672 ± .0003	0.3717 ± .0003	N/A
Water Lettuce 2	0.3166 ± .0003	0.3739 ± .0003	N/A
Creeping Primrose 1	0.3433 ± .0003	0.3770 ± .0003	N/A
Creeping Primrose 2	0.1391 ± .0003	0.3709 ± .0003	N/A
Yellow Lily 1	1.6900 ± .0003	0.3722 ± .0003	N/A
Yellow Lily 2	1.3692 ± .0003	0.3726 ± .0003	N/A

Table 2: Shows the grams of plant food and Nickel that were put in each tank. Note that the amount of plant food in each tank was not important to the concentration of nickel. Also note that the error presented in the chart is only the error attributed to the scale, as the error caused by precipitation of metals and loss to to transportation of powders is unknown. The initial concentrations are unknown due to errors with the AA.

The intent was to have the final concentrations of heavy metals in the respective containers to be .1ppm Lead, 30 ppm Iron, and 15 ppm Nickel. These theoretical levels were based on studies done on waste water in developed as well as developing countries.[ivv] However with inaccuracies introduced by massing and transporting the chemicals combined with the possibility that some of the metals precipitated out immediately after being added, the initial concentrations of metals are as shown in the tables above.

After the plants were placed into their respective tanks, they were allowed to thrive for a period of two weeks. During this time samples were taken of the water in the plants' containers and of the roots, leaves and stems of the plants to determine the heavy metal content of each. The water samples were filtered and then tested using Atomic Absorption Spectroscopy (AA). The plant samples had to be digested first before they were filtered and testing using AA.

To digest the plant samples, the samples were dried in a VWR Model 1305U Utility Oven for 12 hours, then placed in digestion bombs. 5 mL of concentrated (70%) Nitric Acid was placed into the bombs and allowed to react with the plant samples for 15 minutes in a hood. The digestion bombs were then placed in a CEM Model MARS-X for digestion. The system ramped for 5 minutes to a temperature of 175°C and then held at 175°C for 20 minutes followed by a 10 min cool down time. The digestion bombs were then placed in a hood and allowed to cool. After this the bombs were vented in the hood before the contents were filtered. The digestions were filtered with glass filters as a precaution, since the samples were completely dissolved in the acid with no visible debris at the end of digestion. After digestion and filtering, the samples were tested with AA.

Results and Discussion

The results from the iron and lead tanks were excellent. It could not be discovered whether the plants absorbed any nickel because the Atomic Absorption Spectrometer could not accurately read any nickel results. The results from the AA for lead were also occasionally inaccurate because the user miscalibrated the AA for one set of data. The digestion bombs for this research were shared with another research team that was testing for lead content in soil and did not properly clean their equipment. This resulted in inaccurate measurements when the digestion bombs were not checked for cleanliness before use for this research.

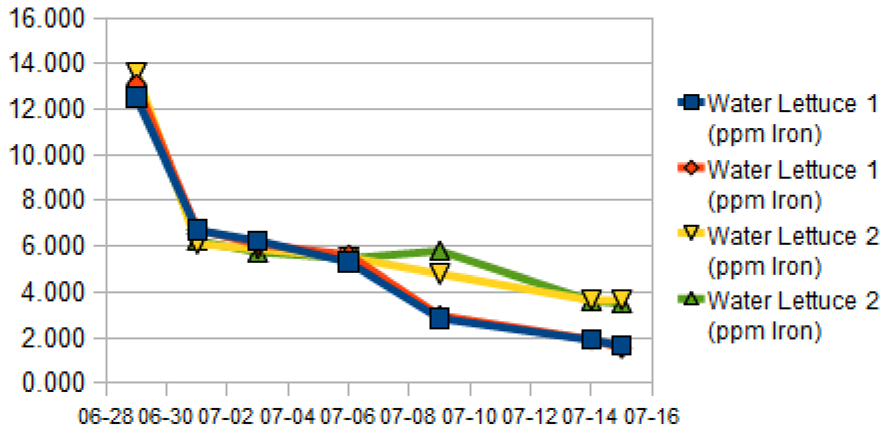

Figure 1: Graph of Iron content in tanks over time. Note that all Water Lettuce plants absorbed the Iron readily, and that most of the absorption occurred in the first two days.

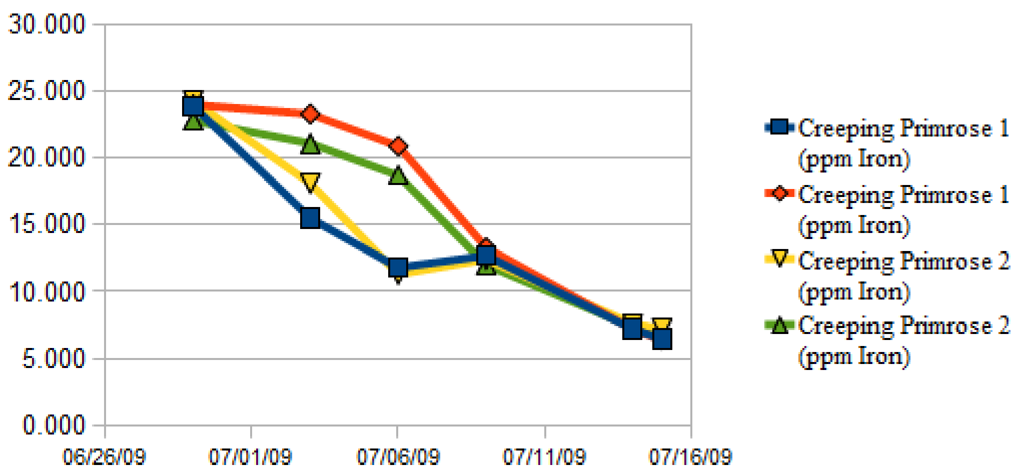

Figure 2: Graph of Iron content in tanks over time. Note that all of the Creeping Primrose absorbed Iron, but at a slower rate than Water Lettuce or Yellow Lily.

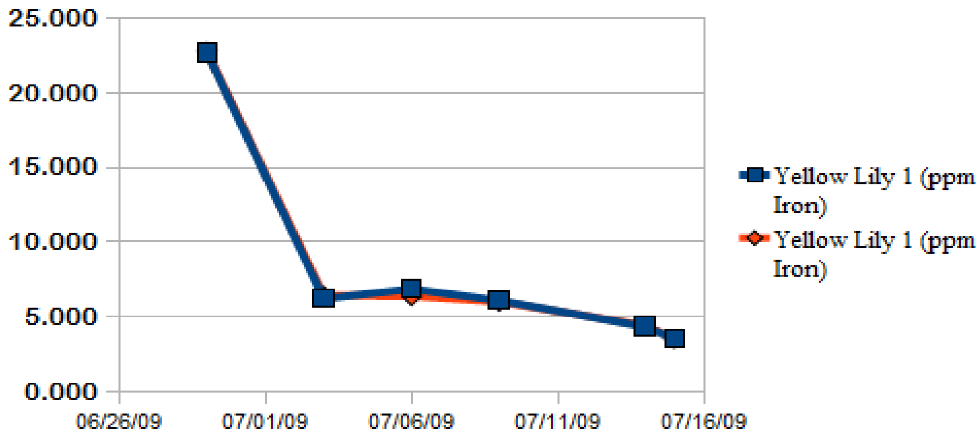

Figure 3: Graph of Iron content in tanks over time. Note that the Yellow Lily absorbed the Iron very readily, and that almost all of the Iron that was absorbed was absorbed in the first four days.

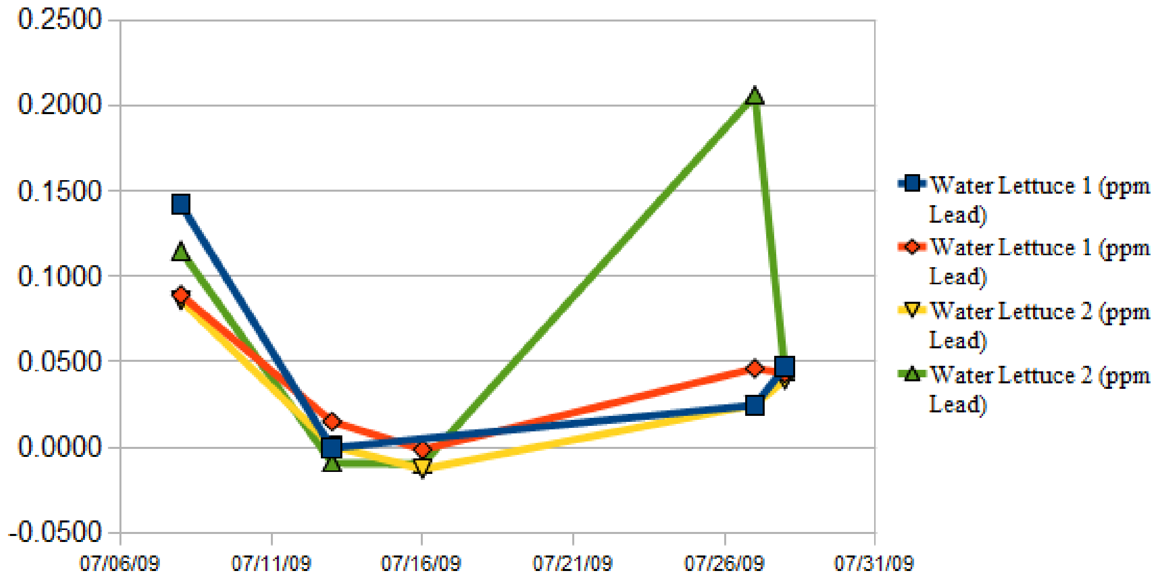

Figure 4: Graph of Lead content in tanks over time. Note that the Water Lettuce absorbed a significant amount of lead. It is also important to not the negative values of lead on 7/11 and 7/16. This is because the AA was calibrated incorrectly while running these samples. There is also a data point on 7/26 that shows an unreasonably high amount of lead. This is due to contaminated equipment.

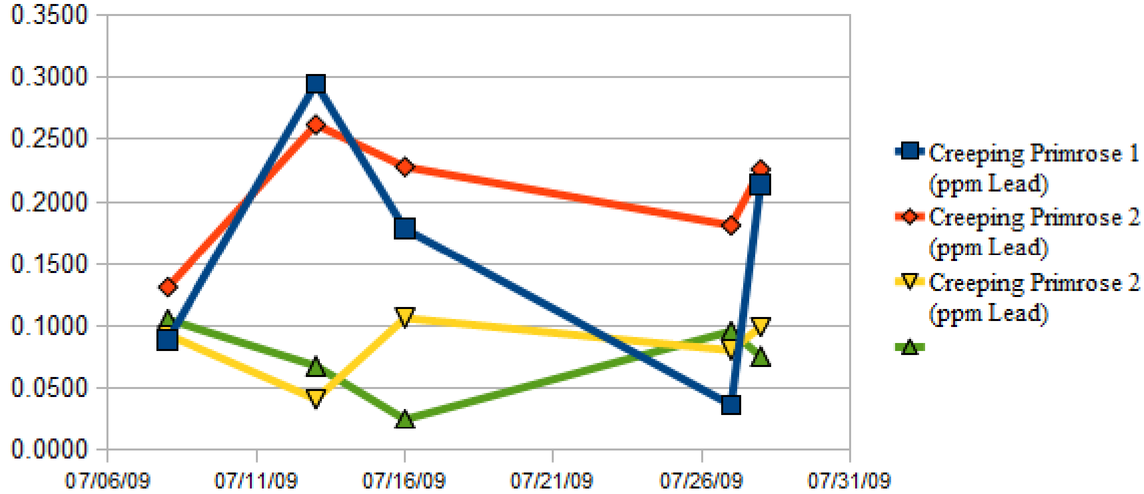

Figure 5: Graph of Lead content in tanks over time. The data for every trend line has a point where it is higher than the initial level of Lead concentration. This should not be true. It is possible that the initial measurements of concentration are wrong, but considering how clustered these initial concentrations are it is unlikely. This erratic data may be caused by a combination of contaminated equipment and bad AA calibrations.

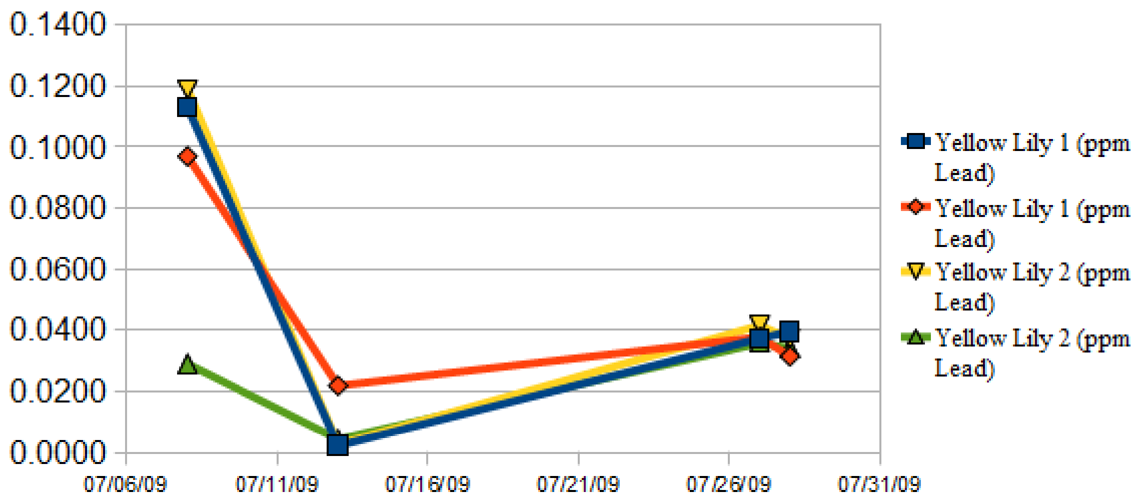

Figure 6: Graph of Lead content in tanks over time. Note that the Yellow Lilies absorbed a significant amount of the initial lead. There is also a dip in the data around 7/12 due to improper calibration of the AA. However it can be seen that the Yellow Lilies do appear to work to absorb heavy metals.

Conclusions

It can be seen from the data that the aquatic plants removed metals from the tanks they were growing in. There were some problems with contamination and improper AA calibrations that made one set of data impossible to interpret and two others slightly inaccurate. However it was still shown that all of the plants had the ability to absorb heavy metals. The fact that all of the aquatic plants absorbed metals is promising, as it shows that there might be many more aquatic plant options for the purpose of waste water treatment.

One surprising discovery in this study is the ability of the aquatic plants to continue to absorb metals after they had been irreparably damaged by the metals. In particular the Water Lettuce plants had their roots and leaves fall off within three days of being placed in the er contaminated with iron.

However the Water Lettuce but continued to absorb Iron for the next week and a half. Similar effects befell the other aquatic plants: the Yellow Lilies had their leaves die and the stems softened considerably. The Creeping Primrose did not die as quickly, since it absorbed the metals more slowly. Instead the leaves all slowly turned brown and fell off, but the stems remained firm and healthy for another week. The plants also never leeched metals back into the water, even after they died.

The results of this study suggest that future work should be done on this topic. One issue that needs to be studied further is the plants leeching metals back into the water. For a more efficient waste water treatment system, the operators need to know when to remove the plants that have absorbed all the metal they can. More work also needs to be done to discover what should be done with the aquatic plants once they have finished removing heavy metals from the waste water. Currently the plants are just put in a different location, where they eventually break down, re-releasing the metals back into the environment. The last thing that should be further researched is the discovery of even more and different aquatic plants for the purpose of waste water treatment.

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