Phytoremediator: Removal of Heavy Metals from Synthetic Aqueous Solution by Water Hyacinth (*Eichhornia Crassipes*)

Myat Lay Nwe[1], Tin Kyaw Oo[2], Ni Ni Linn[3]

Abstract

Toxic heavy metals pollution of water is a major environmental problem in recent world. Floating aquatic plant, water hyacinth is capable of assimilating large quantities of trace elements and heavy metals. Water hyacinth has the ability to absorb heavy metals. Batch experiments were conducted and the uptakes of cadmium, chromium and lead from the synthetic solution for six different concentrations ranging from 5 mg/l to 30 mg/l were studied. The daily uptake of heavy metals for all concentrations was recorded. Samples were analyzed by using AAS (atomic adsorption spectroscopy). Results indicated that at lower concentrations 5 mg/L of heavy metals, the plant growth was normal and the higher removal efficiency was found. At higher concentrations, >15 mg/l, the plant started wilting and removal efficiency was reduced. The AAS results point out the maximum uptake of weight of water hyacinth was 12.70 mg/100g, 12.93 mg/100g and 13.79 mg/100g of in aqueous solutions containing 5 mg/l of cadmium, chromium and lead respectively. Finally, it was concluded that by using water hyacinth, heavy metals could be effectively removed from wastewater when their concentrations were less than 15 mg/l.

Keyword: Phytoremediator, synthetic aqueous solution, water hyacinth, AAS

Introduction

In recent world, the most important concern of environmentalists is the alteration in biogeochemical cycles due to the variety of organic and inorganic pollutants, especially heavy metals released by manmade activities (P. Vara, 2003). With the development of the urbanization and industrialization, different heavy metals in varying concentrations have gradually increased in environment thus resulting in degradation of the environment (F. X. Han, 2002). Heavy metals are highly dangerous for all biotic components of the environment (L. Santona, 2006).

There are many conventional technologies which are being used for degradation of heavy metals from the environment. With the chemical method, not only heavy metals are eliminated but also valuable components of soil get degraded (R. R. Hinchman, 1996). A new innovative eco-friendly technology is known as phytoremediation which utilizes plants for treatment of pollutants (R. L. Chaney, 1996). Some researchers defined phytoremediation as remediation of pollutants from the environment by converting those into less toxic form with the use of green plants (I. Raskin, 1997). According to Environment Protection Guide of USA, the term phytoremediation has been used since 1991 to publish different case studies where plants were utilized to remediate various types of contaminants (A. Rew, 2007).

Numerous aquatic plant species have been identified and tested for their ways in the uptake and accumulation of different heavy metals and organic pollutants in wastewater (M.N.V. Prasad 2006). The water hyacinth, *Eichhornia crassipes*, which is a perennial free floating aquatic plant belonging to the family Pontederiaceae. This plant has high nitrogen content and in combination with cow dung. It can be used for biogas production (Bhattacharya and Pawan, 2010). This technique is a cost-effective plant-based approach for removal of heavy metals from wastewater. The success of

1 *Associate Profess), Dr, Department of Engineering Chemistry, Technological University (Kyaing Tong),
2 *Lecutere, U, Department of Chemistry, University of Mandalay
3 Lecteruer, Daw, Department of Engineering Chemistry, Technological University (Kyaing Tong)

phytoremediation mainly depends on the photo-synthetic activity and the growth rate of plants.

The aim of the present study was to evaluate the phytoremediation potential of water hyacinth (*Eichhornia crassipes*) to remove lead, chromium and cadmium from synthesized aqueous heavy metal solution.

Materials and Method

Plant materials

The study was conducted by using water hyacinth weeds (*Eichhornia crassipes*) which served as tool of phytoremediation. Water hyacinths (WH) were collected from local area of Taungthaman Lake, Amarapura Township, Mandalay Region. The collected samples were rinsed with tap water to remove any epiphytes and insect larvae grown on plants. The sample plants were acclimated for one week to stabilize. The plants were placed in tub with tap water without addition of any nutrient media under natural sunlight for 1 week to let them adapt to the new environment, and then the plants of the same size were selected for the following experiments.

Figure 1. Phytoremediation experiment (adaptation period)

Preparation of metal solutions

Cadmium, chromium and lead solutions were prepared in distilled water with $CdSO_4.H_2O$, $K_2Cr_2O_7$ and $PbSO_4.H_2O$. Standard solutions were prepared in distilled water using cadmium sulfate (100 mg L^{-1}), $K_2Cr_2O_7$ (100 mg L^{-1}) and lead sulfate (100 mg L^{-1}). The removal of Cd (II), Cr (VI) and Pb (II) ion by phytoremediator (water hyacinth) were carried out at room temperature to determine their respective removal capacity.

Metal uptake experiments

Heavy metal uptake of phytoremediators was determined by pot cultivation method and percent uptake that were calculated based on the before and after uptake. The heavy metal contents in aqueous solution were determined by AAS. The removal percentage can be calculated by using equation (1):

$$\text{Removal } \% = \frac{C_0 - C_e}{C_0} \times 100 \qquad (1) \quad \text{(Kavakli, C., 2005)}$$

Once the equilibrium reached, the initial (C_0) and equilibrium (C_e) concentrations were measured by atomic absorption spectrometry (AAS). It is allowed to access to the concentration of uptake metal cation which is the initial metal concentration minus the equilibrium metal concentration (C_o–C_e). From these values, it was possible to obtain the equilibrium adsorption capacity q_e of each adsorbent which was calculated by using Equation (2):

$$q_e = \frac{(C_o - C_e) \times V}{W} \qquad (2) \quad \text{(Kavakli, C., 2005)}$$

Where q_e (mg/g) is the equilibrium adsorption capacity, C_o and C_e are the initial and equilibrium metal concentrations (ppm), respectively. V is the volume of the metal solution and W is the amount of the adsorbent (g).

Determination the Effect of Metal Concentrations

3 L of various concentrations such as 30, 25, 20, 15, 10 and 5 ppm metal aqueous solutions are taken in each plastic container and added 100 g of phytoremediators. These containers were placed in good ventilation place at room temperature for ten days. The remaining metal ion content in the aqueous sample solutions were determined by AAS method for all days and calculated their metal uptake percent.

Figure (2) Phytoremediation experiment in 3L of metal solutions

Determination of the Effect of Dosage

3 L of 100 ppm aqueous solutions were taken in each plastic container and added various dosages of phytoremediators (25 g, 50 g, 75 g and 100 g). These containers were placed in good ventilation place at room temperature for ten days. The remaining metal ion contents in the aqueous sample solutions were determined by AAS method for all days.

Results and Discussion

Heavy metal uptake of phytoremediator were determined by pot cultivation method and percent uptake were calculated based on the before and after uptake. The heavy metal contents in aqueous solution were determined by AAS. In this research work, three heavy metals such as cadmium, chromium (VI) and lead were used for tested metal solution.

Concentration Effect

In the present work, studies on the removal of selected metals were carried out by phytoremediation technique using water floating macrophytes *E. crassipes*. The technique used in this process is called more appropriately rhizofiltration technique, which is a part of phytoremediation. The phytoremediation studies were performed as a function of metal concentration and weight of phytoremediator. The metal content of aqueous water was determined before and after the treatment by using AAS technique. Six metal concentrations (5, 10, 15, 20, 25 and 30 ppm) were prepared and used as wastewater resources. Pot cultivated wetland was firstly construct with 3 L of each prepared metal aqueous solutions and 100 g of phytoremediator.

Table 1. Cd metal uptake ability on water hyacinth with various concentrations

Initial Concentration (ppm)	Cadmium ion Uptake percent of Phytoremediators									
	Day1	Day2	Day3	Day4	Day5	Day 6	Day 7	Day 8	Day 9	Day10
5	11.1	26.3	38.0	46.1	59.8	66.6	71.6	74.6	80.6	83.2
10	18.0	25.0	37.2	41.3	53.4	62.8	69.9	74.4	78.9	80.3
15	7.3	11.3	28.6	36.5	45.3	47.1	53.1	56.2	61.7	66.5
20	4.0	8.5	21.5	23.6	32.9	32.1	32.1	21.6	24.9	22.5
25	3.6	8.4	19.6	22.1	28.1	28.6	27.9	24.3	23.0	20.3
30	2.0	8.3	15.3	21.0	27.8	27.4	27.3	23.3	21.1	19.9

volume - 3L, dosage – 100 g

Adsorption of Cd primarily occurs through roots of the plant. In roots, the tissue in the root tip adsorbed cations from the source. In the presence of root hairs, the efficiency of adsorption processes gets enhanced as the area of contact gets increased which accelerate the pace of Cd ion adsorption via root tissues (I. V. Seregin, 1997).

Water hyacinth (WH) can uptake more cadmium ion when the low metal concentration (5 ppm) and it WH can adsorb 83.2% of Cd during phytoremediation experiment period 10 days. The metal concentration was increased to 10, 15, 20, 25 and 10 ppm. The metal uptake ability of WH was decreased to 80.3 %, 66.5 %, 22.5 %, 20.3 % and 19.9 % respectively. Beyond the metal concentration 15 ppm, the metal uptake ability of WH is appreciable and decreased. Moreover, WH desorbed Cd ion to the metal solution and the plant started wilting. These mean that HW does not uptake the metal at high concentration.

Table 2. Cr metal uptake ability on water hyacinth with various concentrations

Initial Concentration (ppm)	Chromium ion Uptake percent of Phytoremediator									
	Day1	Day2	Day3	Day4	Day 5	Day 6	Day 7	Day 8	Day 9	Day10
5	13.2	20.1	29.6	41.2	48.7	50.7	53.4	69.8	80.2	86.4
10	20.6	21.5	31.6	39.2	48.6	53.9	61.2	68.7	74.3	81.3
15	11.1	18.6	23.7	30.7	35.4	42.1	50.6	53.5	54.2	56.7
20	8.2	11.6	14.7	17.3	21.7	27.2	32.7	37.9	42.1	43.1
25	8.0	9.87	12.3	15.6	19.2	22.4	25.1	27.3	28.9	29.0
30	7.5	8.6	9.4	11.2	13.2	12.9	13.7	14.2	14.8	15.0

volume - 3L, dosage – 100 g

Some researchers point out that cadmium accumulation was more in roots than shoots during all stages of plant growth. Maximum accumulation of total Cr was observed in roots. However, Cr accumulates mainly in roots and shoots; roots accumulate is the major part, with only a small part translocated to the shoots (Sundara-moorthy2010; Paiva2009).

Water hyacinth (WH) can uptake more chromium ion when the low metal concentration (5 ppm) and it WH can adsorb 86.4% of Cr during experiment period 10 days. The metal concentration was increased to 10, 15, 20, 25 and 10 ppm, the metal uptake ability of WH was decreased to 81.3 %, 56.7 %, 43.1 %, 29.0 % and 15.0 % respectively.

Table 3. Pb metal uptake ability on water hyacinth with various concentrations

Initial Concentration (ppm)	Lead ion Uptake percent of Phytoremediator									
	Day1	Day2	Day 3	Day 4	Day5	Day 6	Day 7	Day 8	Day 9	Day10
5	15.2	20.4	30.5	45.7	68.7	72.3	80.4	85.2	90.3	91.4
10	17.2	20.5	31.6	44.3	69.6	74.2	78.6	82.1	89.3	90.1
15	17.0	18.3	19.2	21.3	24.8	25.8	27.0	29.2	30.3	31.2
20	14.3	15.6	17.4	19.2	19.9	17.3	16.2	14.6	12.3	12.0
25	10.8	11.3	11.3	11.3	12.6	13.0	13.2	13.2	13.4	13.5
30	9.7	8.6	9.4	9.3	8.7	8.6	8.6	8.5	8.3	7.6

volume - 3L, dosage – 100 g

In the experiment, first stock solution of chromium was prepared at different concentrations to determine the permeable limit of water hyacinth to uptake lead ion. The results indicated that water hyacinth effectively removed lead from 5 to 30 ppm stock solution, respectively. From standard experiment data, it was observed that, at lower concentration (5 and 10 ppm), water hyacinth is very efficient in reducing 91.4% and 90.1 % of Pb (II) from water. When the metal concentration increased to 15 ppm, the metal uptake ability of WH obviously decreased.

Dosage Effect

Another important factor effect of heavy metal uptake ability is dosage of phytoremediator. The effect of different dosages on Cd, Cr and Pb removal were carried out by varying the dosage from 25 to 100 g/L. 3 L of 5 ppm aqueous metal solution were used for determination. Before and after treatment, the metal concentration was measured by AAS and calculated the percent metal uptake ability based on the results from AAS.

Table 4. Cd metal uptake ability on water hyacinth with different dosage

Dosage (g/3L)	Cadmium ion Uptake percent of Phytoremediator									
	Day1	Day2	Day3	Day4	Day5	Day 6	Day 7	Day 8	Day 9	Day10
25	5.2	7.4	12.1	1.3	20.1	23.1	24.0	24.6	25.3	27.1
50	8.1	13.6	20.1	23.2	31.6	46.2	51.4	57.6	63.1	67.4
75	10.1	16.7	23.1	32.6	44.1	52.3	68.3	70.3	75.2	79.4
100	11.1	26.3	38.0	46.1	59.8	66.6	71.6	74.6	80.6	83.2

volume - 3L, metal concentration – 5 ppm

Table 5. Cr metal uptake ability on water hyacinth with different dosage

Dosage (g/3L)	Chromium ion Uptake percent of Phytoremediator									
	Day1	Day2	Day3	Day4	Day5	Day 6	Day7	Day8	Day9	Day10
25	5.3	6.4	10.6	16.3	21.6	24.1	29.7	32.5	36.4	37.1
50	8.6	12.3	16.7	21.4	32.5	38.7	41.6	49.6	54.3	58.3
75	10.0	16.4	23.2	36.7	42.6	48.6	51.6	55.6	68.1	72.5
100	13.2	20.1	29.6	41.2	48.7	50.7	53.4	69.8	80.2	86.4

volume - 3L, metal concentration – 5 ppm

Table 6. Pb metal uptake ability on water hyacinth with different dosage

Dosage (g/3L)	Lead ion Uptake percent of Phytoremediator									
	Day1	Day2	Day3	Day4	Day5	Day 6	Day7	Day8	Day9	Day10
25	6.4	8.2	11.6	15.4	19.9	23.1	27.1	27.9	28.6	29.0
50	10.0	12.6	16.7	21.7	24.6	29.1	32.9	41.6	54.2	58.6
75	13.6	16.4	23.1	29.9	36.7	48.7	62.4	76.3	80.2	83.2
100	15.2	20.4	30.5	45.7	68.7	72.3	80.4	85.2	90.3	91.4

volume – 3L, metal concentration – 5 ppm

The dose response result of the WH showed that the dosage of materials strongly influenced the amount of Cd (II), Cr (VI) and Pb (II) removed from the solution. Increasing WH from 25 to 100 g/L improved the Cd (II) removal from 27.1 to 83.2 %, Cr (VI) removal from 37.1 to 86.4 % and Pb (II) removal from 29.0 to 91.4%, respectively. It might be speculated that the increased dosage of metal would supply more available active sites.

Sorption Capacity

The most important factor is that adsorption site remains unsaturated during the adsorption reaction. This decrease in adsorption capacity with increase in adsorbent mass is mainly attributed by nonsaturation of the adsorption sites during the adsorption process. Thus, the amount of metal adsorbed onto unit weight of adsorbent gets reduced causing a decrease in equilibrium adsorption capacity, (mg/g), with increasing adsorbent mass. In order to study the sorption capacity on the adsorption of Cd (II), Cr (VI) and Pb (II), a series of adsorption experiments were carried out with different phytoremediator dosages varying from 25 to 100 g at initial concentration of 5 ppm.

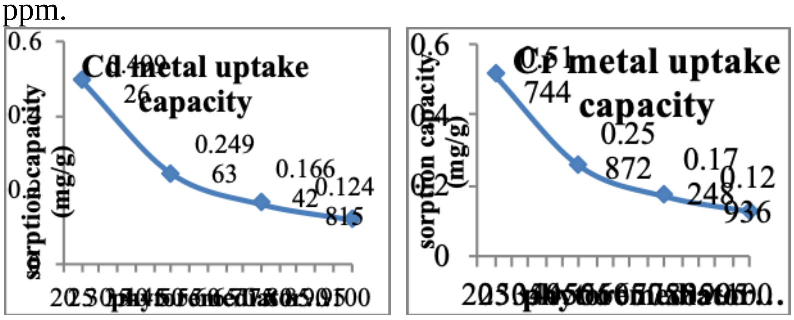

Figure 2. The effect of carbon dose for the uptake of Cd(II), Cr(VI) and Pb (II)

The effect of dose for the uptake of metal by water hyacinth was found to decrease by increasing the adsorbent dose. This may be allocated the amount in grams of adsorbent that is increased the total surface area available for the adsorption of metals reduces as a result of overlapping or aggregation of adsorption sites. Furthermore, maximum quantity adsorbed, q_e = 0.124 mg/g for Cd, q_e = 0.129 mg/g for Cr and q_e = 0.137 mg/g for Pb, was reached by 100 g WH.

Conclusion

The water hyacinth was found to be efficient in reducing the concentrations of Cd (II), Cr(VI) and Pb (II) ions of synthetic water within 10 days of treatment. The experimental results showed that WH has performed extremely well in removing 86.24 % Cr(VI), 83.21 % Cd (II) and 91.36% (Pb) from aqueous metal solutions during 10 days of experimental period. The WH can uptake the following series Pb (II) > Cr (VI) > Cd (II). Phytoremediators can not only improve water quality parameters but also reduce heavy metal in water treatment process. It was found that the removal efficiency increased with the increased in dosage of phytoremediators. Because the larger the surface area with the increased in mass of phytoremediators. The water hyacinth, biosorbent showed a significant ability in removing heavy metals: cadmium, chromium, and Lead from effluent meal solution and it suggest that the availability of water hyacinth in the surrounding communities should be utilized in solving this environmental pollution.

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