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Assessments of Heavy Metal Accumulation Capacity of Selected Plant Species for Phytoremediation: A Case Study in Little Akaki River

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Abstract

Studies on assessments of heavy metal accumulation capacity of selected plant species were carried out in little Akaki river, Addis Ababa city administration, Ethiopia. The aim was to identify plant species and assess the heavy metal accumulation capacity for the Phytoremediation. The heavy metal concentrations in the leaves of selected plant species grown along little Akaki River, soil and water were determined using Atomic Absorption Spectrophotometer at AAEPA. The water analysis result indicated that there was Cd (0.077 mg/L), Cr (0.90 mg/L), Pb (<0.001 mg/L) and Ni (0.034 mg/L) in the river. Similarly, the soil analysis result indicated that Cr (153, 22 mg/L), Ni (30.71 mg/L) and Pb (9.55 mg/L) were detected from the soil but Cd was not detected. The plant analysis result indicated that the species *Arundo donax, Ricinus communis* and *Vernonia amygdalina* had a good potential plant that absorbs Cd, Cr and Pb in different concentrations, while Ni was not detected in the leaves of selected plants. The species *Arundo donax* accumulated Cr (80.90 mg/L), Pb (37.30 mg/L) and Cd (25.98 mg/L), *Vernonia amygdalina* accumulated Cr (83.59 mg/L), Cd (44.46 mg/L) and Pb (14.49 mg/L) and *Ricinus communis* accumulated Cr (62.06 mg/L), Cd (16.64 mg/L) and Pb (16.64 mg/L). It was concluded that the selected plant species had a good accumulation capacity of Cr, Pb and Cd for the phytoremediation activity.

Keywords: Accumulation capacity; Atomic absorption spectrophotometer; Heavy metals; Little Akaki River; Phytoremediation

Introduction

Consequent to global industrialization, heavy metal pollution is a widespread problem which has become a major environmental concern due to hazardous effects on human and environmental health [1,2]. Air and water pollution by metals varies from soil pollution, because heavy metals persevere in soil for a longer time period as compared with the other compartment of the biosphere [3] In the latest decades, the yearly global release of heavy metals attained 22,000 t (metric ton) for cadmium, 939,000 t for copper, 783,000 t for lead, and 1,350,000 t for zinc [4-12].

Many phytoremediation technologies have been used for the remediation of polluted soils and water throughout the World [1,5]. Phytoremediation costs almost one-fourth of the other physical and chemical methods of pollutant treatment [5]. The major advantages of the process include: improvement of the soil quality, as it is driven by solar energy thus suitable to most regions and climates, cost effective and technically feasible process, plants serve as sufficient biomass for rapid remediation; promote high rhizosphere activity and finally restoration in a reasonable time frame of 2 to 3 years [1,2].

The plants, which are often identified as bioaccumulators, have the ability to take up soil contaminants and Deposit them in their roots, as well as in their aboveground organs. According to Kowalska [6,10] it is necessary to point out that bioaccumulating plant species are normally characterized by high concentration factors, i.e., concentrations of the toxic substances are higher in their tissues than in the soil. Bioaccumulation factors of some plants can even reach 1000×. There are plant species capable of intensive uptake of soil contaminants and, at the same time, are characterized by a significant production of biomass [6].

Previous experiments on giant reed suggested that the stem height and diameter, number of nodes, fresh and dry weight of leaves, and net photosynthesis were not affected, indicating that plants tolerated the high concentrations of Cd and Ni [7,9]. On the other hand study conducted by Ref. [6,7]. Phytoremediation of soil polluted by nickel using agricultural crops including ricinus using three levels of treatment (150, 300 and 600 PPM) and one control. Finally he found that the ricinus was efficient in the removal of Ni as compared to others. As giant reed, ricinus plants are very promising energy plants, they can be cultivated in contaminated soils to provide biomass for energy production purposes [7,8]. In this study the species types and concentrations of Cd, Cr, Ni and Pb, of plant species on river bank was investigated for further phytoremediation activity.

Materials and Methods

Description of the study area

This study were conducted on lower part of upper catchment and lower part of middle catchment of little Akaki river, which located in Gulele sub city and Nefas silk lafto sub city respectively, Addis Ababa, Ethiopia. The four sample sites were selected based on preliminary survey (physical observation and discussion with woreda and sub city expert) and literature review than delineated as illustrated (Table 1 and Figure 1).

Sampling and data collection techniques

Samples were collected purposely from closed contaminated river bank which was high industrial and urban waste discharging area and upper catchment of akaki river (control site) no industrial activity. Standard methods of sampling were applied. Total numbers of samples collected altogether were forty (40). These samples were collected and categorized into three (3) major components such as water, soil and plant leaf. Water samples were collected from river the point which

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Site name	Sub city	Woreda	Specific location name
Control site	Gulel sub city	10 & 12	ketena 4 finance
Sample Site 1	Nefas silk lafto	2	below the national liquor and alcohol factory (godo wash)
Sample Site 2	Nefas silk lafto	10	behind Abyssinia leather factory (key afer in local name)
Sample Site 3	Nefas silk lafto	11	below awash leather factory (Awash siga neter deldey)

Table 1: Sample sites and specific location.

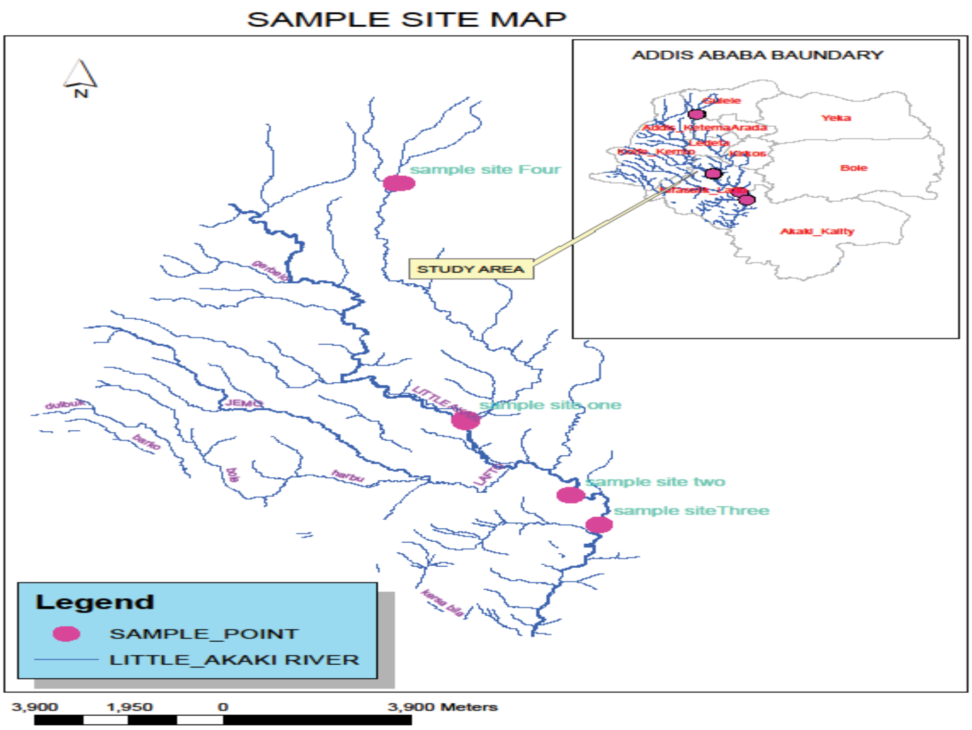

Figure 1: Sample sites of the study area.

pollutant discharging. Soil samples were randomly collected within the river bank whilst plant leaf samples were collected from dominates plant that was growing along the river banks [4,8,9].

Data analysis methods

The elements of interest for these particular analyses were four (4) heavy metals and they are cadmium (Cd), lead (Pb), Chromium (Cr) and Nickel (Ni). All samples were analyzed using Atomic Absorption Spectrophotometer at AAEPA. And the sample data were analyzed and summarized using descriptive statistical methods (percentages) and tabular presentation. Then Comparative analyses were done by following AAEPA standards.

Results and Discussion

Heavy metal concentration in water (HMC)

The water analysis result indicated that there was Cd (0.077 mg/L), Cr (0.90 mg/L), Pb (<0.001 mg/L) and Ni (0.034 mg/L) in the river. Stanley et al. [8] Reported similar result with regard to the presence of these heavy metals (Table 2). And there were concentration difference between each sites (Con. Level of Cr S1>S2>S3, Con. Of Cd S1>S3>S2 and Con. of Ni: S2>S1>S3). According to Yanqun et al. [7] the difference may be due to the pollutant discharging time, sampling time and flow rate of water.

Heavy metal concentration of soils

The soil analysis result indicated that Cr (153,22 mg/L), Ni (30.71 mg/L) and Pb (9.55 mg/L) were detected from the soil but Cd was not detected in all sites as illustrated (Table 3) whereas Pb was detected only site 1 in considerable amount(28.65 mg/L). The reasons may be the types of soil and texture difference, types of plants growth and biomass as reported by Kokyo et al. [10].

Heavy metal concentrations in selected plant species

The identified potential plant species for phytoextraction was *Arundo donax, Ricinus communis* and *Vernonia amygdalina*. These were all local plant species that can adopt easily into the harsh conditions of bare infertile soil after pollution or degraded. The plant analysis result indicated that the species *Arundo donax, Ricinus communis* and *Vernonia amygdalina* had a potential to absorb Cd, Cr and Pb in different concentrations, while Ni was not detected in the leaves of selected plants. The species *Arundo donax* accumulated Cr (80.90 mg/L), Pb (37.30 mg/L) and Cd (25.98 mg/L), *Vernonia amygdalina* accumulated Cr (83.59 mg/L), Cd (44.46 mg/L) and Pb (14.49 mg/L) and *Ricinus communis* accumulated Cr (62.06 mg/L), Cd (16.64 mg/L) and Pb (16.64 mg/L) and illustrated in Tables 4, 5 and 6 respectively. This result was agree with Alebachew [13].

This experimental result indicated that Ni was not detected in all samples of leaf. This finding agree with the result of Yanqun et al. [7] and Alebachew [13] the possible reasons are listed by him is that Ni may be degraded in soil by microorganism activity (Phytodegradation) or stored other part of the plants (phytostablization) or both of them.

Comparative analysis of heavy metal concentration in three plants

The comparative analysis of the three plants indicted that the three heavy metals (Pb, Cr, and Cd) were detected in the tested plant leaves in different concentration, whereas Ni was not detected. According to Tilahun [12] the possible reasons to this concentration difference are growth rate of plants, there ability of absorbed, accumulated capacity of heavy metals in their parts and the depth of root zones or other. As illustrated in Figure 2, *Vernonia amygdalina* had good potential of absorbing and accumulating Cr than the others. While *Arundo donax* had relatively good capacity to store Pb than the others.

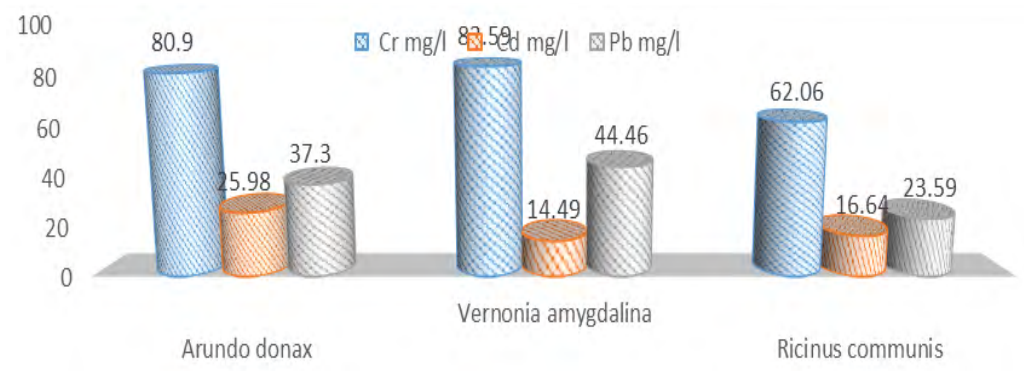

Figure 2: Comparative analysis of heavy metal concentration in 3 plants.

Parameters	HMC in Control Sample	HMC in S1	HMC in S2	HMC in S3
Cd	0.054 mg/L	0.2120 mg/L	0.0044 mg/L	0.015 mg/L
Cr	<0.001 mg/L	1.648 mg/L	1.012 mg/L	0.044 mg/L
Pb	<0.001 mg/L	<0.001 mg/L	<0.001 mg/L	<0.001 mg/L
Ni	<0.5433 mg/L	0.00232 mg/L	0.1007 mg/L	<0.001 mg/L

Table 2: Heavy metal concentration of the water samples and its concentration.

Parameters	HMC in Sco	HMC in S1	HMC in S2	HMC in S3
Cd	ND	ND	ND	ND
Cr	65.10 mg/L	252.77 mg/L	111.00 mg/L	95.90 mg/L
Pb	ND	28.65 mg/L	ND	ND
Ni	43.92 mg/L	23.71 mg/L	42.70 mg/L	25.73 mg/L

Table 3: Heavy metal concentration of the soil samples and its concentration.

Parameters	HMC in Sco	HMC in SS1	HMC in SS2	HMC in SS3	Mean conc. of SS1, 2, 3
Cr	11.80 mg/L	39.9 mg/L	140.8 mg/L	62.00 mg/L	80.90 mg/L
Cd	13.77mg/L	28.04 mg/L	35.58 mg/L	14.31mg/L	25.98 mg/L
Pb	14.8 mg/L	53.23 mg/L	50.00 mg/L	8.68 mg/L	37.30 mg/L
Ni	ND	ND	ND	ND	ND

Table 4: Heavy metal concentration in the leaf *Arundo donax* (Shembeko).

Parameters	HMC in Sco	HMC in S1	HMC in S2	HMC in S3
Cr	8.07 mg/L	12.62 mg/L	31.58 mg/L	141.99 mg/L
Cd	4.50 mg/L	15.38 mg/L	17.90 mg/L	`10.71 mg/L
Pb	ND	62. 90 mg/L	38.50 mg/L	8.68 mg/L
Ni	ND	ND	ND	ND

Table 5: Heavy metal concentration in *Ricinus communis* (Gulo).

Parameters	HMC in Sco	HMC in S1	HMC in S2	HMC in S3
Cr	19.3 mg/L	34.73 mg/L	89.04 mg/L	127.00 mg/L
Cd	8.51 mg/L	7.01 mg/L	14.59 mg/L	21.86 mg/L
Pb	5.63 mg/L	43.96 mg/L	65.08 mg/L	24.34 mg/L
Ni	ND	ND	ND	ND

Table 6: Heavy metal concentration in *Vernonia amygdalina* (Grawa).

Conclusion

This study generally showed that the leaves sample of *Vernonia amygdalina* and *Arundo donax* had high potential of absorbing Cr and Pb comparatively. Whereas the leaves of *Vernonia amygdalina* had high potential of absorbing Cr and Pb paralleled to others plant species. Cd, Pb, Ni and Cr was detected in all sampled (soil, water and leaves), whereas Ni was not detected from all sampled plant species leaves. Therefore planting those plants around polluted river bank for the remediation of Cr, Pb and Cd is very important. This study was conducted infield leaf samples, an extended and detailed experimental study in a controlled manner is necessary.

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