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Research Article

Phytoremediating Activity of Baccharis Latifolia in Soils Contaminated with Heavy Metals

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ABSTRACT

Phytoremediation as an economic alternative with less impact on the environment uses species that accumulate heavy metals in their organs during their development; in this research, the ability of the species *Baccharis latifolia* (Ruiz & Pav.) Pers. - Chilca (Asteraceae) to absorb and accumulate heavy metals such as cadmium, chromium, lead, cobalt and arsenic was evaluated to determine if it is a species potential for phytoremediation processes; the species was collected in Villapinzón (upper basin of the Bogotá River), a sector with a high degree of contamination by heavy metals in water and soil, due to the fact that for decades the tanneries industry has settled in the locality, throwing its waste products to the river without any type of previous treatment; consequently the population have been harmed. The species *B. latifolia* and the soil where it is grown, was collected in the municipality of Villapinzón-Cundinamarca on the banks of the Bogotá river (problem plant) and the other called control plant in the municipality of La Calera-Cundinamarca. To each of the organs (leaves, stem, root) and soil were made an acid digestion process with hydrochloric acid and nitric acid 1: 1, to obtain chlorides and nitrates. The quantification of heavy metals was performed using the atomic absorption technique, the metals analyzed were Cadmium, Lead, Chromium, Cobalt, Lead and Arsenic; as a result we obtained high concentrations for leaf arsenic 103.91 mg/kg, in stem 480.45 mg/kg followed by chromium in leaves 19.54 mg/kg, in stem 136.40 mg/kg; as for the highest root and soil concentration indexes, they were Arsenic with 491.97 mg/kg and 461.77 mg/kg, respectively; and Chromium with 185.09 mg/kg, 1294.43 mg/kg, respectively. According to the results obtained, the species *B. latifolia* can be proposed as an alternative for the phytoremediation process in the sector under study.

Keywords: Atomic absorption, Phytoremediation, heavy metals, *Baccharis latifolia* (Ruiz & Pav.) Pers.

INTRODUCTION

In Colombia there are areas whose soils have, over time, been contaminated with heavy metals by anthropogenic activities; metals that, without being essential for plants, are toxic to humans and to animals that ingest them, when tolerance levels are exceeded[1].

Among these metals are Cadmium (Cd), Chromium (Cr), Lead (Pb), Arsenic (As) and Cobalt (Co). In general, the contamination of soil and water by these elements is derived from the exploitation and smelting of metals, from agricultural inputs, from sludge and residual sediments, from the combustion of coal and oil, chemical industries and of the inadequate disposal of urban and industrial waste[2].

Heavy metal contamination is not only a problem at national and local level, but it is presented worldwide. Glbally, the industries that do not perform treatments to the waste that they produce, they become the main source of contamination of the environment. In the world environment, it is recognized that the tannery industry is highly polluting, as it causes irreversible environmental degradation, which affects the decrease in the quality of life of the population residing nearby[3].

Globally, the heavy metals incorporated into the soil can follow four different routes: the first, being retained in the soil, either dissolved in the aqueous phase of the soil or occupying exchange sites; second, specifically adsorbed on inorganic soil constituents; third, associated with soil organic matter, and fourth, precipitated as pure mixed solids. On the other hand, they can be absorbed by the plants and thus incorporated into the trophic chains; they can pass into the atmosphere through volatilization and can be mobilized to surface or groundwater[4].

The absorption of heavy metals by plants is generally the first step for the entry of these into the food chain. The absorption and subsequent accumulation depend in the first instance on the movement (mobility of species) of metals from the solution in the soil to the root of the plant[5].

In plants, the concept of bioaccumulation means an increase in the concentration of a chemical in a period of time, compared to the concentration of said chemical in the environment[6]. The sensitivity of plant species to heavy

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Table 1: Increasing of analyzed metals in *Baccharis latifolia* (Ruiz & Pav.) Pers., Collected in Villapinzón with respect to the one collected in Calera.

Heavy Metal	Organ	Negative Control	Evaluated area	Difference 95 CI%	P value*
Cadmium	Leaves	9,25±0,33	22,13±0,32	12,87 (11,6-14,0)	0,000
	Stems	12,51±0,37	112,25±0,97	99,74 (96,4-103,0)	0,000
	Roots	16,49±0,38	117,88±0,42	101,39 (99,9-102,8)	0,000
Chromium	Leaves	3,55±0,25	19,54±0,69	15,99 (13,6-18,3)	0,000
	Stems	5,01±0,28	136,40±1,97	131,39 (125,0-137,7)	0,000
	Roots	12,88±1,41	185,09±11,9	172,21 (134,1-210,3)	0,001
Cobalt	Leaves	0,69±0,03	0,75±0,13	0,05 (-0,39-0,5)	0,714
	Stems	0,35±0,10	0,40±0,07	0,05 (-0,26-0,37)	0,674
	Roots	0,46±0,12	0,66±0,08	0,19 (-0,20-0,59)	0,259
Lead	Leaves	4,37±0,26	13,48±0,76	9,11 (6,5-11,6)	0,001
	Stems	4,96±0,31	18,74±0,85	13,77 (10,8-16.6)	0,001
	Roots	19,95±,89	20,10±1,80	0,14 (-25,6-25,9)	0,98
Arsenic	Leaves	46,65±10,80	103,91±8,25	57,26 (22,3-92,2)	0,008
	Stems	99,98±5,37	480,46±8,80	380,47 (351,9-409,1)	0,000
	Roots	102,60±0,73	491,97±9,61	389,36 (358,7-420,0)	0,000

The heavy metal concentrations are expressed in ppm (mg/kg) as the mean ± the standard error of the mean. For the difference in concentrations between the evaluated area and the negative control, the 95% confidence interval was calculated. *Statistical significance was calculated by an unpaired one-tailed t-student test. P <0,05 was considered significant.

Table 2: Transfer ratio of soil metals to the organs evaluated in *Baccharis latifolia* (Ruiz & Pav.) Pers. in Villapinzón-Cundinamarca (Colombia).

	Total plant	Leaves/soil	Stems/soil	Roots/soil	Total plant / soil
Cadmium	252,28	0,18±0,002	0,92±0,007	0,97±0,002	2,07
Chromium	341,05	0,02±0,001	0,11±0,008	0,14±0,014	0,26
Cobalt	1,82	0,35±0,075	0,19±0,034	0,31±0,049	0,86
Lead	52,33	0,50±0,064	0,70±0,062	0,75±0,043	1,95
Arsenic	1.076,35	0,23±0,015	1,04±0,035	1,07±0,031	2,33

metals varies considerably across kingdoms and families, with vascular plants being slightly more tolerant[7].

All plants absorb metals from the soil where they are found, but to a different degree, depending on the plant species and its characteristics and the content of metals in the soil. Plants can adopt different strategies against the presence of metals in their environment, some base their resistance to metals with the strategy of an efficient exclusion of the metal, restricting its transport to the aerial part. Others accumulate the metal in the aerial part in a non-toxic way for the plant. Some plants are able to accumulate large volumes of heavy metals and are known by the term "hyperaccumulators". Hyperaccumulating plants generally have low biomass because they use more energy in the mechanisms needed to adapt to the high concentrations of metal in their tissues[8]. Hyperaccumulation has evolved in more than 400 species of plants distributed in 45 botanical families, being the *Brassicaceae* family one of those that have more genera of this type; family that is distributed all over the world[9].

These plants are viable to remedy the contamination caused by heavy metals in soils, through a process called phytoremediation, which is an ecotechnology based on the ability of some plants to tolerate, absorb, accumulate and degrade pollutant compounds; this technology, at present, is being applied in several countries to recover soils contaminated with organic and inorganic compounds[10].

The genus *Baccharis*, one of the largest of the *Asteraceae* family, includes more than 400 American species of shrubs, occasionally small trees and herbs[11].

Its distribution occurs throughout the world, except in Antarctica[12]. They are abundant in semi-arid, tropical and subtropical regions, Cape Province, South America, Australia and the Mediterranean Region, Russia and the United States[13]. Due to their high adaptation capacity and survival they are very biodiverse, with the possibility of growing in alpine areas of high mountains.

Currently, in the municipality of Villapinzón-Cundinamarca there is a problem of contamination by heavy metals in water and soil, due to the waste products of the tanneries that for decades have been thrown without any type of treatment or specific waste management for the same. This has caused a great environmental impact with the loss of fauna and flora, soil erosion, among other problems to the ecosystem.

Taking into account the aforementioned background, the objective of this work was to determine the phytoremediation activity of the species *Baccharis latifolia* (Ruiz & Pav.) Pers in the upper basin of the Bogotá River in the municipality of Villapinzón.

EXPERIMENTAL

Samples of the plant species and the soil

The species and the soil where it is grown were collected in the western margin of the upper basin of the Bogotá

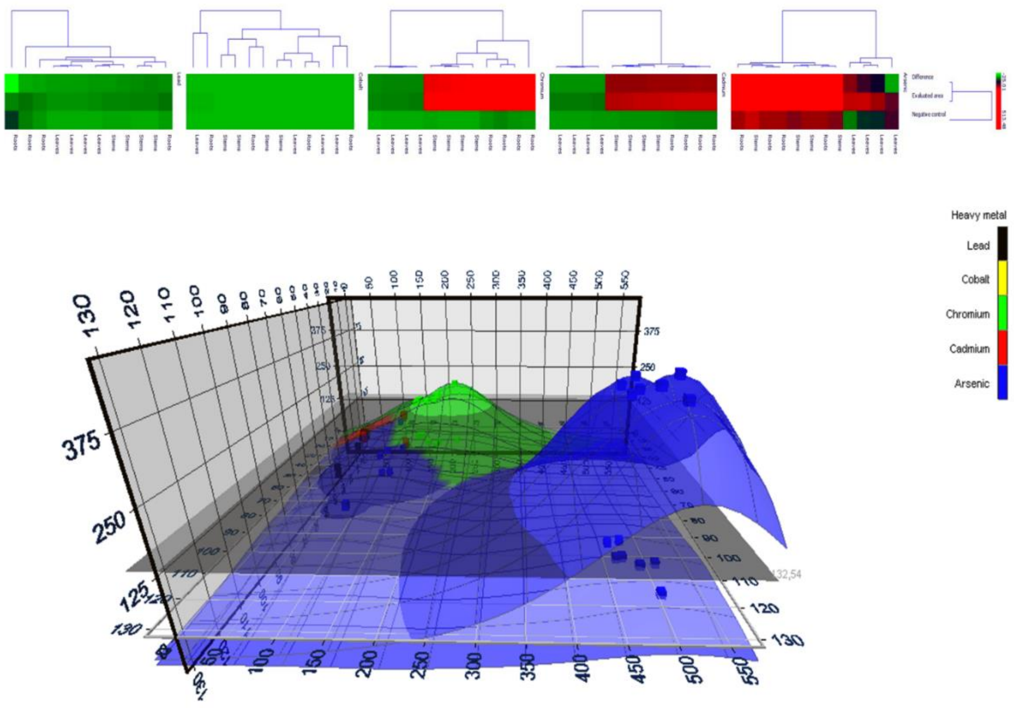

Figure 1: Response surfaces and heat map of the differences in concentrations of heavy metals absorbed by *Baccharis latifolia* between the study area (Villapinzón) and the negative control area (Calera).

River, in the municipality of Villapinzón, an area of high contamination by the tanneries industries, and in the Calera vereda El Volcán, with no presence of sources of contamination, (Cundinamarca-Colombia), as a negative control. A botanical material was taken and delivered to the herbarium of the Institute of Natural Sciences of the National University of Colombia in order to determine the scientific name of the species collected: *Baccharis latifolia* (Ruiz & Pav.) per. COL595900.

Extracts preparation

The samples collected from the plant species were separated into leaves, stems and roots, then dried at room temperature for a week; the same process was carried out for soil samples. Then the plant material was crushed in a knife mill to a particle size suitable for the extraction processes; of the dry and ground organs, 5 g of leaves, stems, roots and soil were weighed, both of the standard species and of the problem species, for a total of 32 samples (four replications).

The acid digestion was carried out with 20 ml of a mixture of nitric acid (HNO_3) and hydrochloric acid (HCl) at 37% (m/m), ratio 1:1, The samples were extracted at reflux, for 24 hours to obtain nitrates and chlorides, subsequently, were filtered; the filtrate was adjusted to 50 ml with water type 1 (T1) in flasks[14].

Determination of the level of heavy metals

The determination of heavy metals was carried out in a flame atomic absorption spectrophotometer equipped with hollow cathode lamps (Varian SPECTRA A 240 FS); the reference curves were made with standard solutions for MERCK atomic absorption, calibrating the equipment for each metal with its respective lamp. The dilutions for calibration were prepared from standard stock solutions (1,000 µg / ml) and T1 water was used for all[15].

Statistic analysis

The values of heavy metals are expressed as the mean (ppm) ± the standard error of the mean (SEM). For the difference in concentrations between the evaluated area and the negative control, the 95% confidence interval was calculated. Statistical significance was calculated by an unpaired one-tailed t-student test. The statistical significance of the transfer ratio was performed by two way-ANOVA with Tukey's post hoc. $P < 0,05$ was considered significant.

RESULTS AND DISCUSSION

The concentrations of heavy metals As, Cd, Cr, Co and Pb were analyzed in each organ of *Baccharis latifolia* (Ruiz & Pav.) Pers. and in the soil (control plant and plant problem).

Table 1 shows the concentrations of cadmium, chromium, cobalt, lead and arsenic in each of the analyzed bodies of *Baccharis*,in the two sectors: upper basin of the Bogotá-Villapinzón and Calera rivers.

According to the results obtained, the main entrance of the heavy metals to the organs of the plant species *Baccharis* is the root, they arrive by diffusion in the medium, by mass flow or by cation exchange. The root has negative charges in its cells, due to the presence of carboxyl groups, which interact with the positive charges of heavy metals, creating a dynamic equilibrium that facilitates entry into the cell interior, either by apoplastic or simplistic[15].

Metal-organ increments

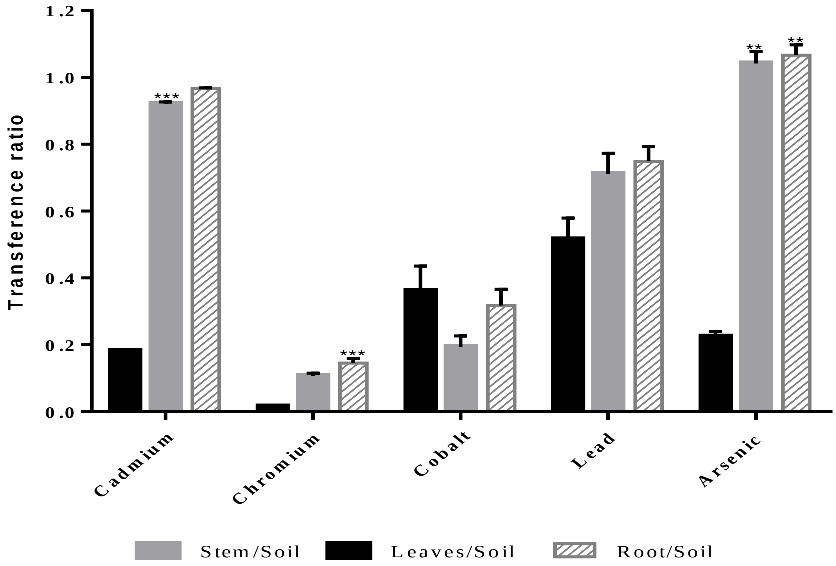

Figure 2: Transfer ratio of heavy metals from the soil to the organs studied of *Baccharis latifolia* (Ruiz & Pav.) Pers. in Villapinzón (Cundinamarca-Colombia).
The transfer ratio is given in mg metal/kg organ (ppm). *** P<0,0001; **P<0,001 with respect to the negative control group. Two way-ANOVA, Tukey post-hoc. Statistical significance for P <0.05

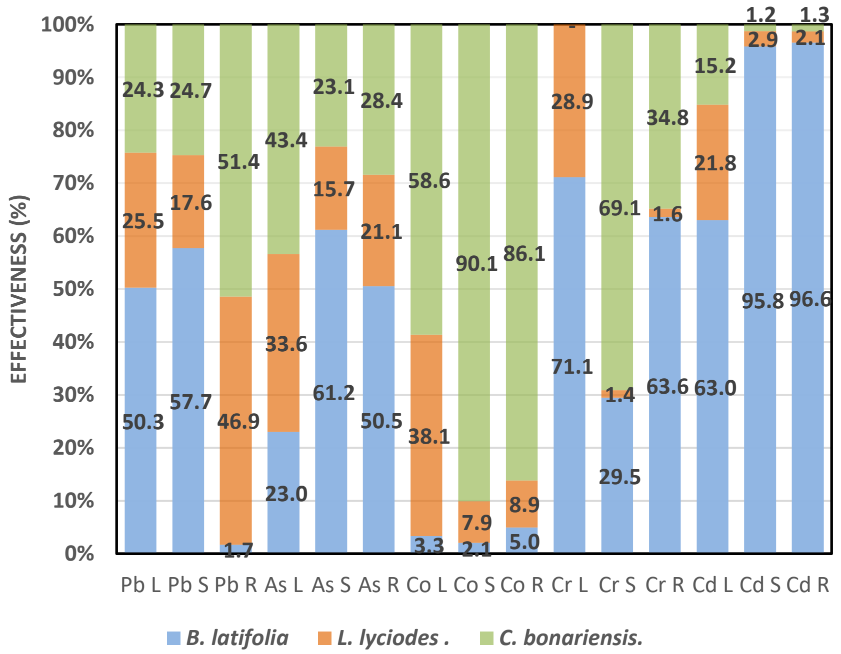

Figure 3: Efficacy of *Baccharis latifolia* (Ruiz & Pav.) Pers. with respect to other species studied in the sector of the upper basin of the Bogotá River (Villapinzón) for the phytoremediation process
L: Leaves; S: Stems; R: Roots

Table 1 shows the increases observed in mg of metal/kg (ppm) of metals selected in the different organs of *Baccharis latifolia* plant by the atomic absorption technique species collected in Villapinzón regarding collected in the Calera; the leaves showed an increase for Cd, Cr, Co, Pb and As of: 12.87; 15.99; 0.05; 9.11; 57.26, respectively. For stems it presents an increase for Cd, Cr, Co, Pb and As of: 94.75; 131.39; 0.05; 13.78; 380.47, respectively. For root presents an increase for Cd, Cr, Co, Pb and As of: 101.39; 172.21; 0.19; 0.14; 389.36, respectively. According to these results, the heavy metal absorbed by the plant studied, which have higher statistically significant increases, relative to the negative control area are arsenic, chromium and cadmium, increments relate to the highest percentages absorbed root and stem.

For the soil where the species develops, there was an increase for Cd, Cr, Co, Pb and As of: 101.07; 1270.94;

0.22; 3.15; 331.57, respectively, being higher for lead and cadmium. This is explained if one considers that on the banks of the Bogotá river there is a large number of agricultural and industrial activities such as tanneries that generate high percentages of heavy metals, increasing levels of pollutants and toxic compounds in water and soil. Figure 1 shows the response surfaces and the heat map of the differences in concentrations of heavy metals absorbed by the species *Baccharis latifolia* in the area of influence (Villapinzón) compared to the negative control area (Calera). The peaks of higher elevation indicate the greatest differences in concentrations of heavy metals absorbed by the species studied, between the area of influence and the negative control area. The most marked differences are observed for arsenic (blue peak), chromium (green peak) and cadmium (red peak). The above is confirmed if the regions of intense red color are observed in the heat map (Arsenic, Chromium and Cadmium). Additionally, it is observed that the clusters of greater influence are related to the difference of concentrations of heavy metals absorbed by the root of *B. latifolia.* The green zones on the heat map are the areas that least intervene with the difference of heavy metals between the two experimental areas (Cobalt and Lead).

Transfer floor - plant

The accumulation of metals for *Baccharis latifolia* that grows in Villapinzón (ppm) (table 2) was for Cd (252.28 mg / kg), Cr (341.05 mg/kg), Co (1.82 mg / kg), Pb (52.33 mg / kg), and As (1076.35 mg / kg). With respect to the transfer ratio of soil metals to the organ in Villapinzón (organ/soil), it was found for leaves: Cd (0.18 mg / kg), Cr (0.02 mg / kg), Co (0.35) mg / kg), Pb (0.50 mg / kg) and As (0.23 mg / kg); for stems: Cd (0.92 mg / kg), Cr (0.11 mg / kg), Co (0.19 mg / kg), Pb (0.70 mg / kg) and As (1.04 mg / kg) kg); in root ratios of: Cd (0.97 mg / kg), Cr (0.14 mg / kg), Co (0.31 mg / kg), Pb (0.75 mg / kg) and As (1.07 mg / kg); and the total plant versus the soil with: Cd (2.07 mg / kg), Cr (0.26 mg / kg), Co (0.86 mg / kg), Pb (1.95 mg / kg) and As (2.33 mg / kg). The above indicates high levels of transfer of soil metals to the different organs of the plant, specifically stems and roots.

Analyzing the total values of transfer of heavy metals to the plant, it is observed that the metals with the highest total plant/soil ratios are Arsenic (2.33), Cadmium (2.07) and Lead (1.95). According to Figure 2, for Cadmium, the highest transfer was presented in the stems, transfer that was statistically significant with respect to the ratio presented in the Calera area (0.62) ($P<0.0001$); for arsenic, the highest transfer ratio was observed in stems and root ($P <0.001$). On the other hand, although the total transfer for Chromium was not significant, the transfer value in the root was ($P <0.0001$).

According to Figure 3, when comparing the plant *Baccharis latifolia* with the *plants Conyza bonariensis*[17] and *Lycianthes lyciodes*[18] it is evident that the metals that most accumulate in these species are Arsenic, Chromium and Lead. The least absorbed metal by these three species is cobalt. Globally, the species *Baccharis latifolia* presents higher values of absorption efficiency of the five metals considered in this study, with respect to the other two species, being more evident for Arsenic.

CONCLUSION

Taking in to account the results obtained in this study, the species *Baccharis latifolia* (Ruiz & Pav. Pers. Shows a high efficiency of absorption and accumulation of heavy metals, especially for Arsenic, Chromium and Cadmium.) The above classifies this plant, as a species with high phytoremediation potential, and that therefore can be included in environmental programs for the management of toxic waste in areas with a high incidence of industrial waste dumping.

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