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ASSESSMENT OF THE PHYTOREMEDIATION POTENTIAL OF *Lycianthes lycioides* (L.) Hassl.

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Abstract

The river Bogotá and its banks show a high contamination by heavy metals like chrome, arsenic, etc., being impacted for decades by anthropic activities including those of tanneries near its source. To restore these riverside soils phytoremediation is employed, which has many socio-economic advantages. Aim: to determine the phytoremediation capacity of the species *Lycianthes lycioides* (L.) Hassl, located in the upper part of the basin of the river Bogotá. Methods: the species which were to be evaluated were gathered in the town of Villapinzón, located at 05° 07' 23.4"N and 73° 39' 10.5"W., which is regarded as a highly contaminated area due to the presence of tanneries, and also in the town of Tenjo, at the Cerro de la Punta. The study employed an acid digestion procedure (using HNO_3: HCl 1:1), with a subsequent quantification of metals like Cd, Cr, Co, Pb and As by the atomic absorption technique with a VARIAN AA140 spectrophotometer. Results: for the species collected in Tenjo the concentrations found were: Leaves: mg/Kg; Cd: 3.58; Cr: 0.05; Co: 2.20; Pb: 3.01; As: 4.94. Stems: mg/Kg; Cd: 4.73. Cr: 0.60. Co: 0.84; Pb: 3.18; As: 20.52. Root: mg/Kg; Cd: 5.65; Cr: 2.51; Co: 0.58; Pb: 3.77; As: 21.53. Soil: mg/Kg; Cd: 7.29; Cr: 3.68; Co: 2.92; Pb: 4.60; As: 28.16. For the species collected in Villapinzón, the concentrations found were: Leaves: mg/Kg; Cd: 8.02; Cr: 6.55; Co: 2.85; Pb: 7.63; As: 88.43. Stems: mg/Kg; Cd: 7.74; Cr: 6.70; o: 1.05; Pb: 7.38; As: 118.13. Root: mg/Kg; Cd: 7.87; Cr: 6.75; Co: 0.93; Pb: 7.78; As: 183.88. Soil: mg/Kg; Cd: 33.95; Cr: 151.14; Co: 16.53; Pb: 45.02; As: 195.84. Conclusions: it was demonstrated that the *Lycianthes lycioides* (L.) Hassl. collected in Villapinzón accumulates a high proportion of chrome and arsenic in its different organs and this confirms its potential for phytoremediation.

Keywords: Heavy metals, *Lycianthes lycioides* (L.) Hassl.

Introduction

The contamination of the river Bogotá is a growing problem due to anthropogenic activities, among which agricultural/stock-rearing and industrial ones stand out. They directly and indirectly affect the environment because of the large amounts of toxic materials shed into waters and the toxic particulate matter emitted into the air. For decades, the river, as it passes through the town of Villapinzón, has received discharges of wastewaters from the tanneries on its outskirts [1-3]. The soils along the banks of the river Bogotá are highly contaminated by heavy metals like chrome, cadmium, arsenic, etc., the data for which has been reported by [4-5]. The heavy metals which are introduced into the soil may follow different routes. The first is that they are retained in the soil, either in a dissolved form in the aqueous phase of the soil or in places of interchange. The second is that they are specifically absorbed by inorganic components of the soil; the third is that they are associated with the organic material in the soil. The fourth is that they are precipitated as pure mixed solids.

Furthermore, they may be absorbed by lichen plants and thus become incorporated in the trophic chains. They may go into the atmosphere through volatilization and may be shifted by surface or subterranean waters. [6-7]. One of the techniques used to recover soils is phytoremediation, which has the following advantages: 1) it may be carried out *in situ* and *ex situ*; 2) it can be done without any need to transport the contaminated substrate, which reduces the spread of the contaminants through the air or waters; 3) it is a sustainable technology; 4) it is efficient, both for the organic and inorganic contaminants; 5) it is a low-cost technology; 6) specialized personnel are not required to carry it out; 7) it does not need to consume energy; 8) it only requires the use of conventional agronomic practices; 9) it does little harm to the environment; 10) it acts positively on the soil, improving its physical and chemical properties, due to the formation of a vegetal cover; 11) it is highly likely to be accepted by the public, since it is aesthetically pleasing; 12) it avoids the use of excavation and heavy vehicles; 13) it can be used in waters, soils, the air and sediments; 14) it provides for the recycling of materials (waters, biomass, metals). [8].

The sensitivity of species to heavy metals varies in accordance with different vegetal kingdoms and families: vascular plants are the most tolerant [9]. Plants employ different strategies to handle the heavy metals in their environment. Some reject the metals, efficiently excluding them by stopping them from moving to their aerial parts. Others accumulate the metals in a non-toxic form in their aerial parts. Exclusion is more characteristic of sensitive species which are tolerant of the metals; and accumulation is more common among species which are always present in contaminated soils. [10-11].

Lycianthes is a genus of plants belonging to the Solanoideae subfamily of the family of the Solanaceae. It consists of 150 species which are native to Asia and America, essentially in the Southern Cone of South America. *Lycianthes lycioides* (L.) Hassl. has a variety of vernacular names in Colombia, like: "*gurrubo*" (the Departments of Boyacá and Cundinamarca); "*gurrumo*" (Cundinamarca); "*zombo*" (Boyacá); "*sambo*" (Boyacá. Cundinamarca); and "*coban*", "*tote*" and "*saúco*". The leaves of this species are used in an infusion or decoction to "cleanse" the blood. In the popular medicine of the country, it is thought that washing the skin with a decoction of the leaves and fruits of these plants will heal pimples and pustules on a person´s face. It is a shrub which grows to a height of up to 140 cm. It has a branched and woody stem, lanceolate leaves, with a very short petiole, which are whole and arranged in fascicles. It has blue flowers which are actinomorphic, gamosepalous, gamopetalous and infundibuliform. Its androecium is formed by 5 epipetal stamens. It has dithecous and basifixed anthers; a gynoecium with a superior bicarpelar ovary that is bilocular, with parietal placentation; and an apical style and bifid stigma. Its fruits are in the form of berries and have been used as an orange dye. Its grows in sandy/stony soils on mountain slopes and dry river beds at an altitude of between 2500 and 3300 meters above sea level.

Materials and Methods

Obtention of the vegetal samples

The samples of the de *Lycianthes lycioides* (L.) Hassl. species were collected on the west bank of the upper basin of the river Bogotá, between Villapinzón, a region highly contaminated by tanneries, and in Tenjo (Cundinamarca, Colombia) as a control for non-contamination by metals, due to the absence of industries in that area.

Obtention of the extracts

The material was dried at room temperature for a week, then pulverized in a mill to reach a particle size suitable for the extraction processes. 5g of each organ of the plant were subjected to digestion by HCL: HNO_3 1:1, then set to 25 ml with type-1 water. The contents of Pb, Cr, As, Co and Cd were determined by the atomic absorption technique, using a Varian 240 FS spectrophotometer.

Results

Table 1 shows the concentration in mg. of metal/Kg of organ (ppm) of the metals found in *Lycianthes lycioides* (L.) Hassl. by the technique of atomic absorption of the samples collected in Villapinzón and Tenjo.

High levels of Cr, Pb, Cd, Co and As were found in Villapinzón samples, compared to the Tenjo samples. The leaves showed increments for Cr (1: 33.8), Pb (1: 2.5), Cd (1: 2.2), Co (1: 1.3) and As, (1: 17.9). For stems the increments were for Cr (1: 11.1), Pb (1: 2.3), Cd (1: 1.6), Co (1: 1.3) and As (1: 5.8). For the root the increases were for Cr (1: 2.7), Pb (1: 2.1), Cd (1: 1.4), Co (1: 1.6) and As (1: 8.5). And in the soil where the plants grow, the increments were: Cr (1: 41,0), Pb (1: 9,8), Cd (1: 4,7), Co (1: 5,7) and (1: 7.0).

The accumulation of metals in the samples of *Lycianthes lycioides* (L.) Hassl. which grow in Villapinzón (ppm) were: for Cr (20.0); for Pb (22.8); for Cd (23.6); for Co (4.8) and for As (390.4).

The proportional transference of the metals in the soil to the organ in the plants from Villapinzón (organ/soil) were: for the leaves: Cr (0.04), Pb (0.17), Cd (0.24), Co (0.17) and As (0.45); for the stems: Cr (0.04), Pb (0.16), Cd (0.23), Co (0.06) and As (0.60); and for the roots: Cr (0.04), Pb (0.17), Cd (0.23), Co (0.06) and As (0.94). The proportions for the whole plant compared to the soil were: Cr (0.13), Pb (0.51), Cd (0.70), Co (0.29) and As (1.99), which indicate high levels of transference of the metals in the soil to the organ, with proportions of 13.2% and 199.4% for the movement of the metals in the soil to the plant.

When we compare these data with those found for *Conyza bonariensis* (L.) Cronq and the soil in the same area, we find that the organ/soil proportions (ppm) were: For the leaves: Cr (0.0), Pb (0.42), Cd (0.61), Co (0.40) and As (0.43); For the stems: Cr (2.27), Pb (1.00), Cd (0.73), Co (0.47) and As (0.79); For the root: Cr (0.68), Pb (0.45), Cd (0.84), Co (0.69) and As (1.23); And for the whole plant compared to the soil: Cr (2.95), Pb (1.87), Cd (2.18), Co (1.56) and As (2.45) [5].

In the case of *Zea* maize, the levels of Cr accumulation were 2538 ppm [12]; In *Pteris vittata* 23 ppm As [13]; In *Sesbania drummondi* 1687 ppm Cd [14], and in *Vetiveria zizanioides*, the levels of root accumulation and outbreaks were for Cr (ppm) 1750 and 18, for Cd (ppm): 14.2 and 0.31, As (Ppm): 268 and 11.2. [15-16].We can thus conclude that *Lycianthes lycioides* (L.) Hassl is a species with a strong potential for the phytoremediation of soils contaminated with heavy metals.

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Conflicts of interest

The authors declare that they do not face any conflicts of interest in this article.

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Table 1. ppm of metal found in samples of *Lycianthes lycioides* (L.) Hassl collected en Tenjo (Tenj) and Villapinzón (Vipz) and their respective increases. (Δ)

Organ of plant	Metal	Pattern mg metal/kg organ: Tenj	mg metal/kg organ:Vipz	Increase (Δ)	Proportion Tenj : Vipz
Leaves	Arsenic	4.94	88.43	83.49	1 : 17.9
	Chrome	0.19	6.55	6.35	1 : 33.8
	Cobalt	2.20	2.85	0.65	1 : 1.3
	Cadmium	3.58	8.02	4.45	1 : 2.2
	Lead	3.01	7.63	4.62	1 : 2.5
Stems	Arsenic	20.52	118.13	97.61	1 : 5.8
	Chrome	0.60	6.70	6.09	1 : 11.1
	Cobalt	0.84	1.05	0.21	1 : 1.3
	Cadmium	4.73	7.74	3.02	1 : 1.6
	Lead	3.18	7.38	4.20	1 : 2.3
Root	Arsenic	21.53	183.88	162.35	1 : 8.5
	Chrome	2.51	6.75	4.24	1 : 2.7
	Cobalt	0.58	0.93	0.35	1 : 1.6
	Cadmium	5.65	7.87	2.22	1 : 1.4
	Lead	3.77	7.78	4.01	1 : 2.1
Soil	Arsenic	28.16	195.84	167.67	1 : 7.0
	Chrome	3.68	151.14	147.46	1 : 41.0
	Cobalt	2.92	16.53	13.61	1 : 5.7
	Cadmium	7.29	33.95	26.67	1 : 4.7
	Lead	4.60	45.02	40.41	1 : 9.8