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Capacity of two vegetative species of heavy metal accumulation

Capacidad de dos especies vegetativas en la acumulación de metales pesados

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Abstract

Habitat fragmentation allows for vegetative species to be used as indicators of environmental pollution by heavy metals. Considering the distribution of *Prosopis laevigata* (mesquite) and *Schinus molle* (pepper tree) heavy metal concentrations were determined as potential indicators of environmental impact assessment for agricultural and livestock, rural settlement, commercial and service, urban settlement and mining land uses. A total of 30 sampling points were established during summer, autumn, winter and spring, based on the presence of the two species. Applying the technique of ICP-MS, concentrations of Al, As, Co, Cu, Cd, Pb, Ti, V and Zn were determined. With a statistic model the interactions between species, type of land use and season with respect to the concentration of these minerals in the leaf material were determined. Results indicated that the presence of heavy metals is determined by the effect of the species, land use and season, and the possible association between these. The specie of mesquite was the most efficient for bioaccumulation of Pb, Co and Al. In the same way, the pepper tree was more efficient with respect to Ti. On one hand, trees located in the mining land use showed the highest concentrations of Cu, Zn, Cd, Pb, Co and As. On the other hand, the spring season presented the highest concentration of Cu, Zn, Co, Ti and V. With that, it could be demonstrated that As, Co, Cd, Pb, Ti and Zn concentrations were above the normal limit. Therefore, the dynamics and functionality, environmental factors and physiological differences to develop physical-chemical processes in the absorption and transport of these elements towards the leaves are a determining factor of vegetative species placed under conditions of fragmentation, are good elements for surveying on pollution and environmental impact.

Keywords
pollution • foliar matter • land use • season • heavy metal

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Resumen

La fragmentación del hábitat permite aprovechar especies vegetativas como indicadoras de contaminación ambiental por metales pesados. Considerando la distribución de *Prosopis laevigata* (mezquite) y *Schinus molle* (pirul) se determinaron las concentraciones de metales pesados en material foliar para evaluar el impacto ambiental de los usos de suelo agropecuario, residencial rural, comercial y servicio, residencial urbano y minero. Fueron establecidos 30 puntos de muestro durante las estaciones de verano, otoño, invierno y primavera, basados en la presencia de las dos especies. Aplicando la Técnica ICP-MS fueron determinadas las concentraciones de Al, As, Co, Cu, Cd, Pb, Ti, V y Zn. Con un ANOVA se probaron las interacciones entre especie, tipo de uso de suelo y estación con respecto a la concentración de estos minerales en material foliar. Los resultados indicaron que la presencia de metales pesados está condicionada por el efecto de la especie, uso de suelo y la estación, así como la posible asociación entre estos. El mezquite resultó ser más eficiente en la bioacumulación de Pb, Co y Al. En el caso del pirul solo fue más eficiente con respecto al Ti. Los árboles ubicados en el uso de suelo minero obtuvieron las mayores concentraciones de Cu, Zn, Cd, Pb, Co y As. Por otra parte, la estación de primavera incidió en la mayor concentración de Cu, Co, Ti y V. Con esto se pudo demostrar que As, Co, Cd, Pb Ti y Zn presentaron concentraciones arriba del límite normal en material foliar. Por lo tanto, la dinámica y funcionalidad, factores ambientales y diferencias fisiológicas para desarrollar procesos físico-químicos en la absorción y transporte de estos elementos hacia las hojas son un factor determinante de las especies vegetativas situadas bajo condición de fragmentación, lo que contribuye ser un buen elemento de estudio de la contaminación y evaluación del impacto ambiental.

Palabras clave

contaminación • material foliar • usos de suelo • temporada • metales pesados

Introduction

Pollution by heavy metals (HM) can be assessed by making use of plant species that grow in fragmented habitats, serving as environmental indicators (21, 24). HM are severe pollutants in the environment due to their toxicity, persistence and bioaccumulation problems (9). Furthermore, it is presence in the earth crust is lower to 0.1 % and generally lower than 0.01 % (28). These are classified into two groups trace elements or micronutrients (As, B, Co, Cr, Cu, Mo, Mn, Ni, Se and Zn) necessary in small quantities for organisms, but toxic once past a certain threshold and without known biological function (Ba, Cd, Hg, Pb, Sb, Bi) (29).

Some classifications of elements that are considered in this study, locate Cu and Zn within the group of trace elements and micronutrients, being these necessary for essential functions of the plants. The micronutrients are defined a chemical element necessary for plant growth found in small amounts, usually < 100 mg kg^{-1} in the plant.; and the As is considered ultratrace non-metallic elements and the metallic elements are located some as Cd, Cr, Co, Pb, Ni, and V (34). In the dynamics of the entrance of heavy metals in the plants are associated the soil contamination, the dynamics of heavy metals in the soil, transport and toxicity of metals (31). Pollution in soil, air and water is possible to originate an accumulation of toxic elements in plant tissue. Hence, it is necessary to carry out leaf analysis to assess their concentration, where the selection of samples may include the entire plant or specific sections of it, such as the leafstalk, roots and leaves (8, 19, 28).

The HM are built up in street dust and on the plant leaves through atmospheric deposition related to sediments, impact and interception (38). This could be influenced by the aerodynamic effect of the woods or wooded area primarily because of the surface roughness of the woodland and turbulence generated in the wind (18). In general, the pollutant measurement central is located in urban areas, and there are few permanent registers from the outskirts such as those in the rural sector and natural areas. This situation worsens when it´s the case of rural and industrial mining zones where the background, historical and indicator levels are unknown concerning the degree of pollution. Under these conditions the leaves of plants play an important role as a receptor of the atmospheric dust and as a baseline for the differential degree of pollution (18, 22).

Plants are used as direct or indirect elements of decontaminating. In the first case, plants participate in the modification of the pollutant quantity through absorption, sequestration or accumulation. Trees are also candidates in the practice of recovery, but the environmental consequences of their usage differ to those of herbaceous plants; this is due to their growth form, chemical composition, and longevity (25). The foliage analysis is a procedure to determine the elemental concentration in the leaves that reflect trees nutritional status, deficiency, or toxicity. It can also provide information like the concentration of metals (27). It may be used as preventive practice and quality control as well as being used as environmental pollution index (18). In the state of San Luis Potosi, the municipalities of Soledad de Graciano Sanchez and San Luis Potosi, considered to be the most populated of the region (29, 35, 36), exhibit a rural-urban connectivity, highlighting the infrastructure and motion of agricultural areas, livestock farming, mining, resource banks, roads, vehicular traffic, as well as industrial influence, business and service expansion and rural and urban housing (35, 36). This has caused fragmentation in the distribution of some species and has developed studies to assess the environmental impact of the human activities, above all the presence of heavy metals due to the usual extraction of metallic and non-metallic minerals in these zones (37).

The presence of lead, zinc, arsenic, and cadmium in the environment and in urine and hair was found in children of San Luis Potosi (11, 20). The objective of this work was to determine the presence of heavy metals in *Prosopis laevigata* (mesquite) and *Schinus molle* (pepper tree), prevalent species with fragmented distribution from different land uses, in San Luis Potosi.

Materials and methods

The study area was located in the state of San Luis Potosi, within the rural-urban sector between the municipalities of Soledad de Graciano Sanchez and San Luis Potosí. The municipality of Soledad de Graciano Sanchez lies between 22°10'59" N and 100°56'27" W, and the San Luis Potosi at 22°08'59" N, 100°58'30" W with an altitude between 1.849 and 1.864 m (29).

The climate is dry template with warm summers, BSOKw[11] *e.g.* according to Koeppen´s classification. The annual rainfall is 400 mm, mostly concentrated in summer and fall (from May to October).

Dominant soil types are litosol, xerosol, feozem, castañozem y fluvisol (35). *Propospis laevigata* (mesquite) and *Shinus molle* (pepper tree) are located in fragmented ground paths of five types dominant land uses: agricultural and livestock, rural settlement, commercial and service, urban settlement, and mining. This ground path formed an ecological corridor, allowed to locate 30 sample areas (figure 1, pag 127) and where previous studies have shown the presence of heavy metals in soil and sediments riparian area (4, 6).

The main criterion was the presence of the two species in each land use and sampling point due to habitat fragmentation conditions. In each land use, 30 to 40 g of foliar matter was taken of each species from single branches longer than 1.60 m. All sampled trees were located alongside a highway, alternating on the left and right sides, as well as their exposure to sources of pollution and airflow.

The samples were taken from the same exemplars during the summer and fall seasons of 2009, in addition in winter and spring of 2010, gathering 120 samples during the studied period. In order to determine the concentration of metals, a 0.5 g of foliar matter was incinerated in a muffle furnace at 450°C (dry digestion), addition of HNO_3 to 1%, filtering it, and complete at 25 ml in a volumetric flask for the analysis of de Al, As, Co, Cu, Cd, Pb, Ti, V y Zn by using of the ICP-MS technique in Laboratory of the Institute of Geology of the Autonomous University of San Luis Potosi.

The concentrations of metal were reported in mg $kg^{-1.}$ For the data analysis (ANOVA) a was designed by Minitab, set to $\alpha \leq 0.05$, testing the interactions between the use, type of land, species and season in reference to the concentration of heavy metals. A correlation analysis was carried out (Pearson's correlation coefficients), and in addition to principal component analysis (PCA) was performed.

Results and discussion

The general averages found in the analyzed elements of the leaves were on the basis of Al (266.0 mg kg^{-1}) > Zn (21.75 mg kg^{-1}) > Cu (5.2 mg kg^{-1}) > Ti (4.21 mg kg^{-1}) > V (2.62 mg kg^{-1}) > Pb (2.05 mg kg^{-1}) > As (0.45 mg kg^{-1}) > Cr (0.42 mg kg^{-1}) > Cd (0.11 mg kg^{-1}) > Co (0.06 mg kg^{-1}). On the other hand, there were considerable associations between the concentrations of heavy metals in the leaves, species, land use, season, and the double interaction between species-land use and land use-season.

Species effect

The species factor had a significant effect in the concentrations of Al (p=0.000), Co (p=0.035), Pb (p=0.077) and Ti (p=0.004). The relation of results can be seen in table 1 (page 128). The species of mesquite concentrated the highest amount of Al (406.7±23 mg kg^{-1}), being highlighted the difference of 137.5 mg kg^{-1} in the concentrations of Al in mesquite to those found in the pepper tree. The concentrations of Al in plants are found on an average of 200 mg kg^{-1} ranging between 10 a 1000 mg kg^{-1} (34). Regarding Co, the mesquite resulted with a concentration of 0.11±0.009 mg kg^{-1}, obtaining 0.03 mg kg^{-1} more than the pepper tree, being above the average which is of 0.2 mg kg^{-1} (34).

In mature leaf tissue of various plants, the normal range is 0.02-1 ppm; it can be toxic to plants (23).

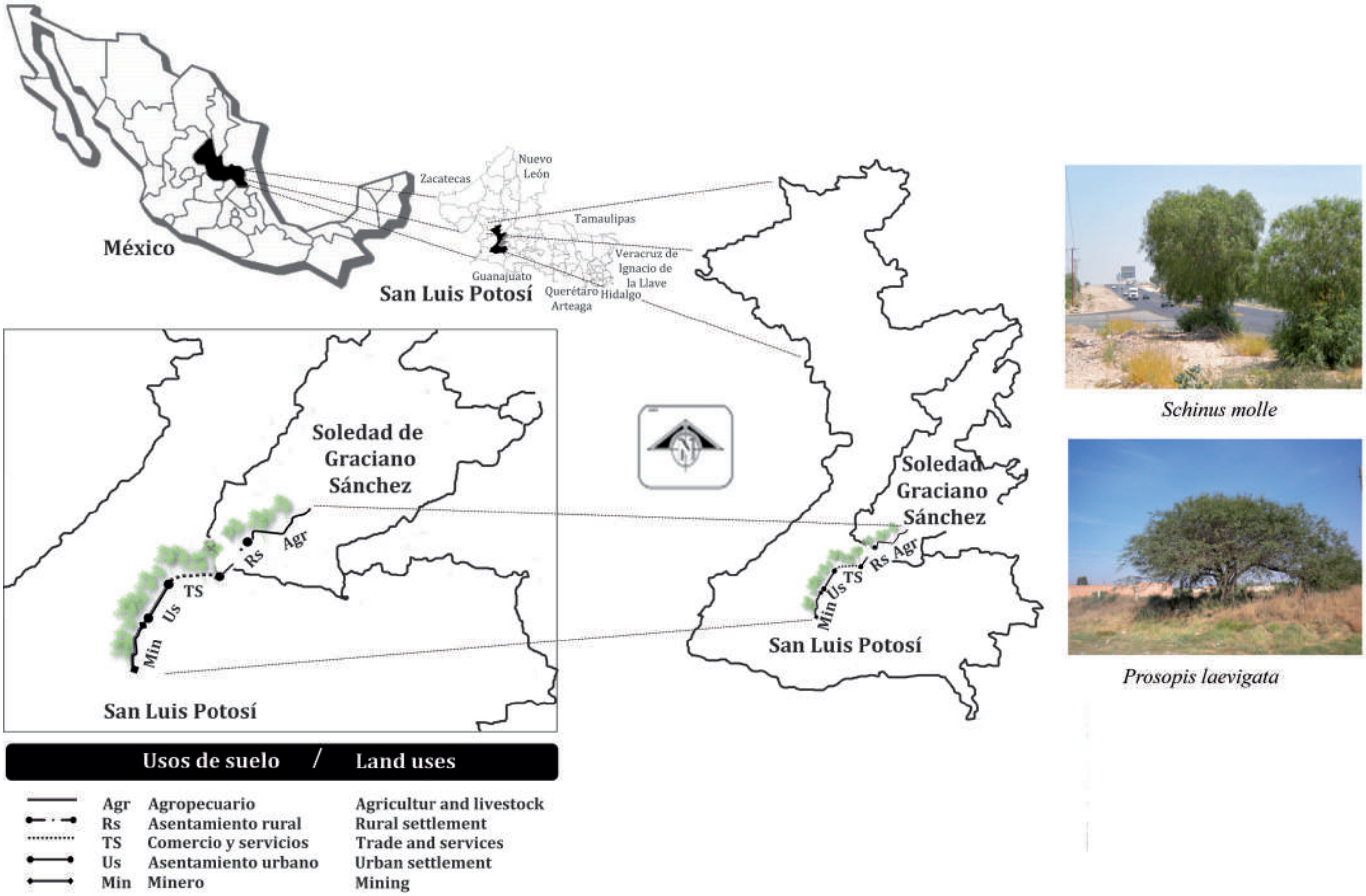

Figure 1. Location of the study area.

Figura 1. Localización del área de estudio.

Table 1. Ratio of the concentrations of heavy metals in foliar matter according to the species effect.

Tabla 1. Relación de las concentraciones de metales pesados en material foliar de acuerdo con el efecto de la especie.

Species	**Pb** (mg kg^{-1})		**Co** (mg kg^{-1})		**Al** (mg kg^{-1})		**Ti** (mg kg^{-1})	
	Mean	±E.E.	Mean	±E.E.	Mean	±E.E.	Mean	±E.E.
P. laevigata	7.08	1.02	0.11	0.009	406.7	23	4.14	0.18
S. molle	4.52	1.02	0.08	0.009	269.2	23	4.92	0.18

In respect to Pb, the concentration was of 7.08±1.02 mg kg^{-1}, obtaining a difference of de 2.56 mg kg^{-1} between the mesquite and the pepper tree, over-passing the limit of normal content which is of 1.0 mg kg^{-1} (34). In reference to the concentrations of Ti, the highest amount was present in the pepper tree with 4.92±0.18 mg kg^{-1}, being above the normal range of 0.1 to 4.6 (34). The ratio species-season showed substantial incidence in the concentrations of Ti (p=0.006) and V (p=0.000). These results are shown in figures 2 (page 128) and 3 (page 129).

Regarding Ti, the highest concentration was present in the pepper tree during the season of spring with 7.47±0.376 mg kg^{-1}, being above average range from 0.1 to 4.6, its presence is considered as an indicator of pollution in land and atmospheric dust (34). In respect to V, the highest concentration was obtained from the pepper tree in spring with 3.66±0.143 mg kg^{-1}. In reference to V (p=0.019), its highest concentration was in the pepper tree and in the commercial and service land use with 3.09±0.160 mg kg^{-1}, the V concentrations in plants varied from 0.27 to 4.2 mg kg^{-1} (34).

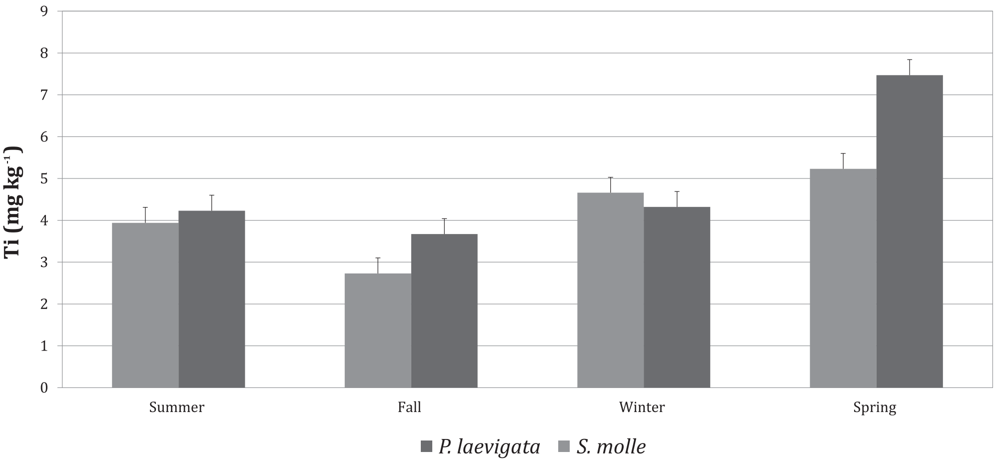

Figure 2. Ratio of the Titanium concentrations according to the species-season effect.

Figura 2. Relación de las concentraciones de Titanio de acuerdo con el efecto especie-temporada.

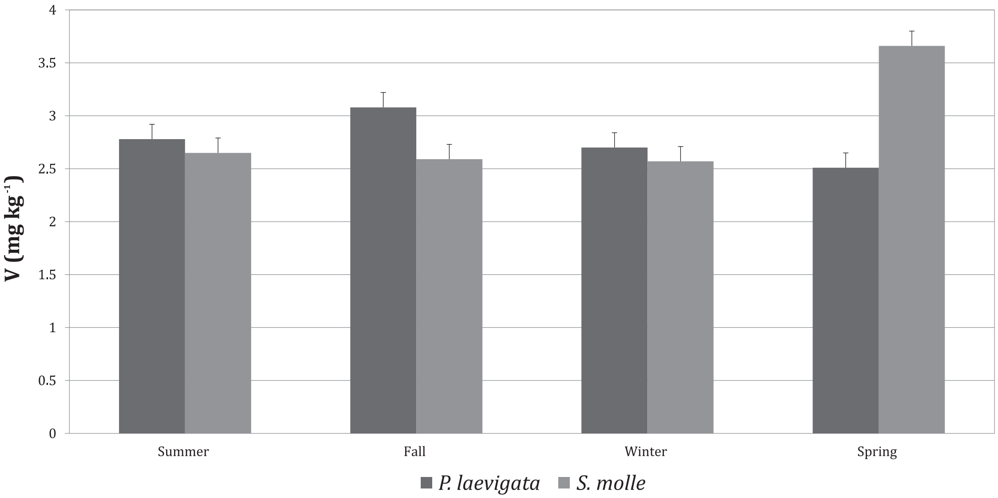

Figure 3. Ratio of the Vanadium concentrations according to the species-season effect.

Figura 3. Relación de las concentraciones de Vanadio de acuerdo con el efecto especie- temporada.

Regarding Ti, the pepper tree concentrated the highest amount in the urban settlement area with 6.11 mg kg^{-1} (figures 4 and 5, page 130), similar values were found in *Platanus occidentalis* (3). This element is linked to the removal of the earth´s crust, especially to particles of dust (26). On the whole, the presence of the assessed elements can be attributed to the atmospheric disposition caused by industrialization and by emissions of automotives (41). These elements have been found in similar studies with tree species (3, 10, 38). The bioaccumulation patterns in plant species vary as well as the same elements, therefore the results cannot be extrapolated (30). Also, the natural sensibility or tolerance of plants in accumulating metals is substantially different according to the species and the genotypes (39).

Land use effect

In the case of the land use and considered all samples of two species, this was substantially significant for the concentrations of Al (p=0.000), Cd (p=0.000), Co (p=0.030), Cu (p=0.002), Pb (p=0.000), Ti (p=0.000), and Zn (p=0.000), mainly because of its high concentration in trees found in the mining and the urban residential land use. These results are shown in table 2 (page 131). The mining and metal industries are associated to soil, air and water pollution with different potentially toxic elements such as lead and zinc (33). This may be having an effect in the concentration of these elements in both studied plant species. On the other hand, the content of elements in plants differs according to the level of pollution in the soil, but the differences between soils may be moderately or highly polluted (39). In reference to the use of mining land, most concentrations of Cd were 1.29±0.150 mg kg^{-1}. The content of this element varies from 0.1 a 1.0 mg kg^{-1}, and could have various effects over the plants such as on photosynthesis and the interruption the flow of mineral elements (34).

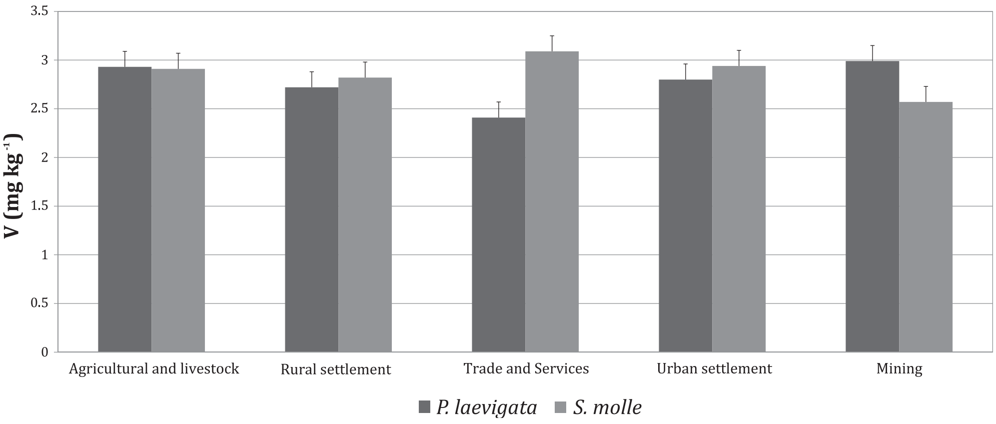

Figure 4. Ratio of the Vanadium concentrations according to the species-land use effect.

Figura 4. Relación de las concentraciones de Vanadio de acuerdo con el efecto especie-uso de suelo.

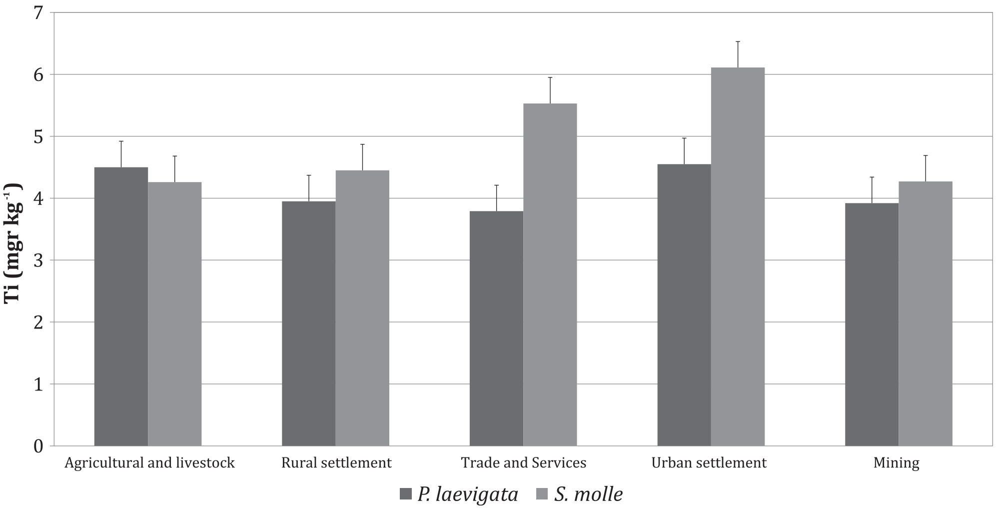

Figura 5. Ratio of the Titanium concentrations according to the species-land use effect.

Figura 5. Relación de las concentraciones de Titanio de acuerdo con el efecto especie-usos de suelo.

Table 2. Ratio of the concentrations of heavy metals in foliar matter (two species) according to the land use effect.

Tabla 2. Relación de las concentraciones de metales pesados en material foliar (dos especies) de acuerdo con el uso de suelo.

Land uses	**Cu** (mg kg^{-1})		**Zn** (mg kg^{-1})		**Cd** (mg kg^{-1})		**Pb** (mg kg^{-1})		**Co** (mg kg^{-1})		**Ti** (mg kg^{-1})		**Al** (mg kg^{-1})		**As** (mg kg^{-1})	
	Mean	±E.E.	Mean	±E.E.	Mean	±E.E.	Mean	±E.E.	Mean	±E.E.	Mean	±E.E.	Mean	±E.E.	Mean	±E.E.
Agricultural and livestock	5.53	1.5	35.05	20.6	0.12	0.15	2.56	1.6	0.08	0.015	4.38	0.29	286.68	36.4	0.49	0.22
Rural settlement	5.11	1.5	27.94	20.6	0.15	0.15	2.81	1.6	0.07	0.015	4.2	0.29	282.95	36.4	0.5	0.22
Trade and services	7.77	1.5	64.14	20.6	0.44	0.15	4.65	1.6	0.1	0.015	4.66	0.29	243.7	36.4	0.56	0.22
Urban settlement	6.31	1.5	48.12	20.6	0.27	0.15	4.71	1.6	0.1	0.015	5.33	0.29	487.48	36.4	0.75	0.22
Mining	15.2	1.5	155	20.6	1.29	0.15	14.28	1.6	0.13	0.015	4.1	0.29	289.78	36.4	2.21	0.22

In mature leaf tissue of various plants, the normal range Cd is 0.05-0.02 ppm; excessive or toxic levels range from 5-30 ppm (23). In regard to Co, the highest concentration was of 0.13±0.015 mg kg^{-1}. It's a natural element found in rocks, land, water, plants and animals. It´s associated to alloys used in the manufacture of engines, cutting and grinding tools, and is used to color glass, ceramics, paints, and as a drier for porcelain enamels and porcelain paints (14). The Cu had its highest concentration with 15.2±1.5 mg kg^{-1}. Copper is usually found near mines, foundries, industrial plants, landfills and waste disposal sites. At extremely high levels toxic effects might occur. It's associated with copper compounds that can be found in the environment, dust, air and land, vegetation in decomposition, and forest fires (13).

The concentrations of this element can be due to the presence of particles emanated by the copper foundries of the industrial zone (11). In regard to the Pb, the highest concentration was of 14.28±1.6 mg kg^{-1}. This indicates that it is above the limit of normal content in plants of 1.0 mg kg^{-1} (34). The Zn was of 155±20.6 mg kg^{-1}, the highest concentration found in this land use. The content of Zn in plants varies from 10 to 100 mg kg^{-1} (34). Most of the Zn in the environment is the result of mining, mineral refining, manufacturing of steel, and coal and waste incineration (15).

The level of zinc in the land increases mainly because of to the disposal of residues by industries that manufacture metal and by coal ash brought about from power plants. The Zn is an essential element for plant growth and has an important role in the biosynthesis of enzymes. While comparing the trends of the concentrations of these elements, it is highlighted that the rural settlement land use mostly had the least concentrations (2). Its presence may be due to being used as an agent for tire repair and caused by vehicle pneumatic motor wear. The automobile tire abrasion increases especially in semi-arid environments (32, 38). The concentrations of Cu showed a difference of 10.09 mg kg^{-1}, the Pb was of 11.72 mg kg^{-1} and the Zn was of 127.06 mg kg^{-1}. In reference to the concentrations obtained in the urban settlement, the plant species showed higher Al concentrations of 487.48±36.4 mg kg^{-1} y Ti 5.33±0.29 mg kg^{-1}, being above normal range of 0.1 to 4.6, associating their presence as a pollutant indicator in land and atmospheric dust (34).

The highest concentration of Al was in trees leaves localized in urban land use with 487.8 mg kg^{-1}, twice the concentration obtained in the commercial and service land use. The levels of Al in the air generally vary between 0.005 y 0.18 micrograms per cubic meter (μg/m^3) of air, depending on the location, the weather conditions, and the type and level of the industrial activity in the area. Most of the Al in the air is found hovering in small dust particles. The levels of Al in urban and industrial areas may be higher and could vary between 0.4 y 8.0 μg/m^3 (17).

Season effect

The season factor had a significant effect in the concentrations of Al (p=0.086), Co (p=0.000), Cu (p=0.002), Ti (p=0.000), V (p=0.011) and Zn (p=0.099) (table 3, page 133) considered all samples of two species. The highest concentrations of Al were registered in winter (391.2±32.56 mg kg^{-1}) and the lowest in fall with 277.6±0.009 mg kg^{-1}, showing a difference of 113.6 mg kg^{-1}. In regard to Zn, the highest concentration was in winter with 98.1±18.4 mg kg^{-1} and the lowest in summer with 40.1±18.4 mg kg^{-1}, having a difference of 58 mg kg^{-1}. The amount of Zn in plants vary from 10 a 100 mg kg^{-1} (34).

Table 3. Ratio of the concentrations of heavy metals in foliar matter (two species) according to the season effect.

Tabla 3. Relación de las concentraciones de metales pesados en material foliar (dos especies) de acuerdo con el efecto de la temporada.

Season	**Cu** (mg kg^{-1})		**Zn** (mg kg^{-1})		**Co** (mg kg^{-1})		**Ti** (mg kg^{-1})		**Al** (mg kg^{-1})		**V** (mg kg^{-1})	
	Mean	±E.E.	Mean	±E.E.	Mean	±E.E.	Mean	±E.E.	Mean	±E.E.	Mean	±E.E.
Summer	5.13	1.35	40.1	18.4	0.08	0.013	4.09	0.26	324.1	32.56	2.72	0.1
Fall	6.27	1.35	48.3	18.4	0.06	0.013	3.2	0.26	277.6	32.56	2.83	0.1
Winter	8.58	1.35	98.1	18.4	0.12	0.013	4.49	0.26	391.2	32.56	2.64	0.1
Spring	11.97	1.35	77.7	18.4	0.14	0.013	6.35	0.26	358.8	32.56	3.09	0.1

For copper, the highest concentration wasinspringwith11.97±1.35mgkg^{-1}andthe lowest in summer with 5.13 ±1.35 mg kg^{-1}. The contents of this element in plants vary from 10 a 100 mg kg^{-1} (34). Ti was higher in spring with 6.35±0.26 mg kg^{-1} and lower in fall with 3.2±0.26 mg kg^{-1}. Also Vanadium had its highest concentration in spring with 3.09±0.1 mg kg^{-1} and the lowest in winter with 2.64±0.1. The concentration of this element in plants varies from de 0.27 a 4.6 mg kg^{-1}.

Use of land season-effect

Considered all samples of the two species, the relation between land use and season had a significant effect in the concentrations of As (p=0.009), V (p=0.080) y Pb (p=0.014) (table 4, page 134). The As exhibited the highest concentration on the land use mining-autumn with 3.81±0.44 mg kg^{-1} and the lowest in the residential use rural-autumn with 0.22±0.44 mg kg^{-1}, having a difference of 3.59 mg kg^{-1}. The normal concentration of this element in plants varies from 0.009 a 1.7 mg kg^{-1}, which indicates being above this range (34). Arsenic origins in natural form in land and minerals and therefore may go into the air, water and to the soil as dust carried in the wind. The concentration of arsenic on land varies broadly, in general between 1 and 40 parts of arsenic per million of parts of land (ppm) with an average of 3 to 4 ppm. However, the land near the geological deposits rich in arsenic near some mines and foundries, or in agricultural areas where pesticides were used with arsenic in the past may have higher levels of arsenic (16). Vanadium had the highest amount in the use commercial and service-winter 3.53±0.22 mg kg^{-1} and the least concentration in the use of residential land rural-spring (2.38 mg kg^{-1}). Vanadium is usually mixed with other metals creating alloys. Vanadium in the form of vanadium rust is a component of a special kind of steel used in automobile parts, springs, and ball bearings. Vanadium is also blended with iron to manufacture parts for airplane engines. Small amounts of Vanadium are used to manufacture rubber, plastic, ceramic, and other chemical products (12). The concentrations of this element in plants varies from 0.27 to 4.2 mg kg^{-1} (34). In regard to Pb, its highest concentration was in the land use mining-fall with 27.67±3.21 mg kg^{-1} and the least in rural residential land use with 1.08 mg kg^{-1}±3.21 having a difference of 26.59 mg kg^{-1}. This indicates that it is above the limit of normal content in plants of 1.0 mg kg^{-1} (34).

Table 4. Ratio of the concentrations of heavy metals in foliar matter (two species) according to the land use-season effect.

Tabla 4. Relación de las concentraciones de metales pesados en material foliar (dos especies) de acuerdo con el efecto uso de suelo-temporada.

Land uses	Season	V (mg kg^{-1})		As (mg kg^{-1})		Pb (mg kg^{-1})	
		Mean	±E.E.	Mean	±E.E.	Mean	±E.E.
Agricultural and livestock	Summer	2.71	0.22	0.31	0.44	1.41	3.21
	Fall	3.12	0.22	0.33	0.44	1.8	3.21
	Winter	2.9	0.22	0.72	0.44	3.81	3.21
	Spring	2.95	0.22	0.58	0.44	3.21	3.21
Rural settlement	Summer	2.96	0.22	1.01	0.44	5.72	3.21
	Fall	3.09	0.22	0.22	0.44	1.08	3.21
	Winter	2.38	0.22	0.28	0.44	2.05	3.21
	Spring	2.66	0.22	0.51	0.44	2.37	3.21
Trade and services	Summer	2.43	0.22	0.48	0.44	4.4	3.21
	Fall	2.39	0.22	0.25	0.44	2.18	3.21
	Winter	2.64	0.22	0.7	0.44	8.27	3.21
	Spring	3.53	0.22	0.81	0.44	3.76	3.21
Urban settlement	Summer	2.69	0.22	0.61	0.44	4.21	3.21
	Fall	2.76	0.22	0.43	0.44	3.08	3.21
	Winter	2.74	0.22	0.6	0.44	4.95	3.21
	Spring	3.3	0.22	1.34	0.44	6.61	3.21
Mining	Summer	2.79	0.22	1.15	0.44	7.92	3.21
	Fall	2.81	0.22	3.81	0.44	27.67	3.21
	Winter	2.53	0.22	1.12	0.44	10.45	3.21
	Spring	3	0.22	2.78	0.44	11.09	3.21

Lead is generally added to the environment by deposition of dust and from roads and highways in proportion to the density of traffic and the distance from the edge of the highway (1, 2). The levels of some pollutants may depend on the region, the weather conditions, and the type and level of the industrial activity in the area (17). On the other hand, these results may be influenced by the aerodynamic effect of the forest or arboreal area, mainly due to the surface roughness of the forest mass and the turbulence caused by the wind, present in different seasons (18).

Analysis of the coefficient of correlation and PCA

The Pearson´s coefficient of correlation test provided significant ratios from which Cu-Co (0.817), Zn-Cu (0.855), Zn-Co (0.785), Ti-Al (0.656), Pb-As (0.903), Cd-Cu (0.884) y Cd-Zn (0.953) ratios stand out. For such reason, the studied species comply with some of the criteria in order to be considered as bio monitors (2).

The first three components explained 71% of the variability in the original data (42, 19, 10%) obtained from the nine heavy metals that were analyzed. The dispersion diagram was built with the PC1 and PC2, which explained as a whole 61% of the variability of the original data. PC1 resulted positive correlations of which higher values were of the Co (0.38), Cu (0.37), Cd (0.37), Zn (0.35) and Pb (0.32). El PC2 presented positive correlations with high values highlighting Al (0.46) y Ti (0.42) (figure 6), to a large extent the influence of the land use of the urban and mining settlement as well as that of the species of mesquite and the winter season show data that have an effect upon this variability. Twelve samples are primarily observed throughout the PC1 away from the interception axis between PC1 and PC2 (89, 177, 117, 137, 140, 147, 202, 207, 208, 223, 234, 237, 5, 158, 110, 191, 30 y 142). In figure 6, it distinguishs the samples 140 and 147 distant from the central axis. The first belonging to *P. laevigata* and the use of urban settlement land. In the original data presented the highest values of heavy metal concentrations, reaching 2346 mg kg^{-1} Al, 0.90 mg kg^{-1} of As, 0.28 mg kg^{-1} Co, 6.37 mg kg^{-1} of Cu, 0.843 6.37 mg kg^{-1} of V, 10.9 mg kg^{-1} Pb, 6.97 mg kg^{-1} of Ti, 3.08 mg kg^{-1} of V and 168.4 Mg kg^{-1} of Zn. In regard to sample 147 which belongs to the *S. molle* and mining land use, showed high values of original data the Al (662.5 mg kg^{-1}), As (1.50 mg kg^{-1}), 0.698 mg kg^{-1} of Co,

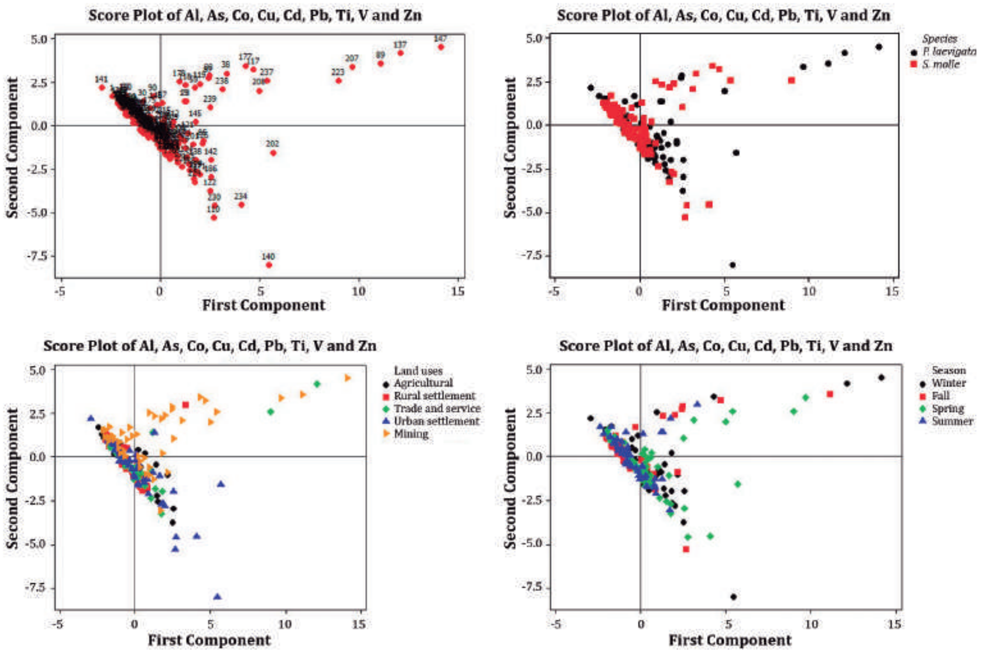

Figure 6. Point distributions derived of principal component analysis considering the factors of land use, species and season.

Figura 6. Distribución de puntos derivado del ánalisis de componentes principales considerando los factores usos de suelo, especie y temporada.

88.02 mg kg^{-1} of Cu, 9.33 mg kg^{-1} of Cd, 56.10 mg kg^{-1} of Pb, 9.24 mg kg^{-1} of Ti, 3.19 mg kg^{-1} of V y 1304.5 mg kg^{-1} of Zn. Similar results were found, attributing the presence of these elements in the environment to the influence of the urban and mining activity in the area (5, 7).

Figure 7 shows a cluster derived from the distances of correlation coefficient between the heavy metals studied, indicating the degree of affinity between As and Pb with a level of 96.8 %; on the contrary, V presents a lowest degree of affinity.

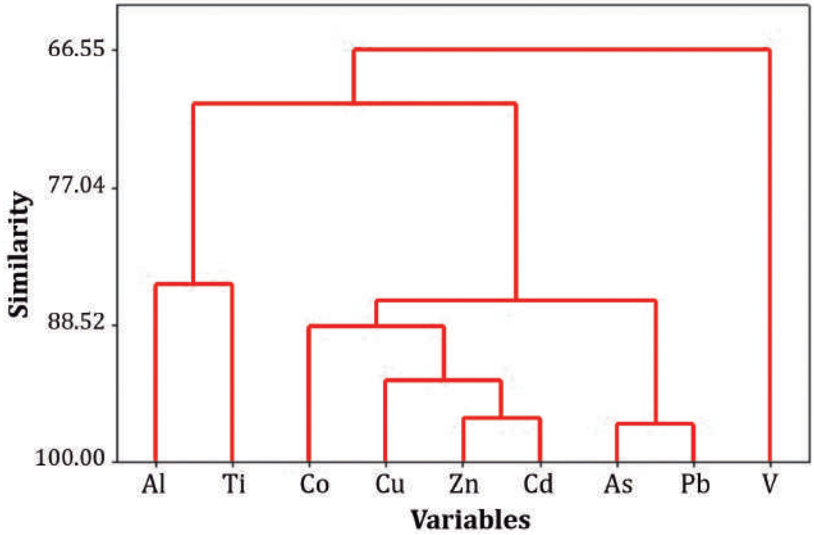

Figure 7. Dendogram of similarity of Euclidean distance between the studied metals foliar matter.

Figura 7. Dendrograma de similitud de la distancia euclidiana entre los metales estudiados en material foliar.

Conclusions

Results indicated that the presence of heavy metals is determined by the individual effect of the species, land use, and season as well as the possible association between them. *P. laevigata* turned out to be more efficient in the bio-indication of Pb, Co and Al than the *S. molle*, that was more efficient with respect to Ti. The use of mining land resulted in higher concentrations of Cu, Zn, Cd, Pb, Co and As, having significatively impacted in six of the eight assessed elements. On the other hand, the spring season presented the most amount concentrations of Cu, Co, Ti and V. In winter season Zn was the most represented concentrations. In this way, As, Co, Cd, Pb Ti and Zn showed concentrations above normal values for the vegetative species. It is evident that in addition to the influence of anthropogenic activities, environmental factors and physiological differences to develop physical-chemical processes in the absorption and transport of these elements towards the leaves are a determining factor. Therefore, the dynamics and functionality of vegetative plant species studied under conditions of fragmentation are good elements for assessment on pollution and environmental impact of antropogenic activities such as the different the land uses.

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