Article

Biomonitoring of heavy metals in tree vegetation in the city of Saltillo

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Abstract

Heavy metal contamination is a serious problem worldwide and in some regions of Mexico. In cities, this is mainly due to residues or waste from industry and vehicle flow. This study focuses on determining the concentration of heavy metals (Cd, Cr, Pb and V) in tree species leaves (*Pinus halepensis* Mill., *Cupressus sempervirens* L. and *Prosopis* spp.). These species were selected with the purpose of being used as environmental quality bioindicators in the city of Saltillo, Coahuila, Mexico. 15 sampling points were established, of which 13 points were randomly distributed in the city of Saltillo and two points outside the urban area. Sampling was carried out in July 2019 (summer period). The heavy metal content was determined by the inductively coupled plasma optical emission spectroscopy (ICP-OES) technique. Interactions between species-site factors with respect to heavy metal concentrations were tested, which were determined by the averages obtained between the samples and their duplicates. It is highlighted that the species factor *C. sempervirens* resulted in the highest concentration of heavy metals in Cd, Pb and V, as well as *P. halepensis* in Cr. Points 3, 4, 12 and 15 resulted in the highest concentrations of the metals analysed, these points are located in the southeast and central areas of the city of Saltillo. The use of tree species as heavy metal bioindicators in the city of Saltillo can be a viable tool for monitoring environmental quality.

Keywords: bioindicator, industry waste, leaves, pollution, urban development.

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Introduction

The rapid growth of urban and industrial systems has led to various environmental impacts (Rodríguez *et al*., 2017), such as the increasing emission into the environment of pollutants from industry, such as the release of massive amounts of carbon dioxide, oxides of sulfur and nitrogen, dust, total suspended particles and toxic chemicals (Henry *et al*., 1999).

The economic activities of the place, transport and mobility infrastructure, as well as the physiographic characteristics of the region are among the main factors of this problem (SEMA, 2017). Among total suspended particles (PST), atmospheric pollution by heavy metals (MP) in cities can be found, such as Pb, Cd, Ni, Cu, Cr, (Fernández *et al*., 2000; Cruz *et al*., 2013), as well as Zn, Sb, Ba depending on the type of industry present in the region (Rodríguez *et al*., 2017).

The main sources of MP pollution are mining, metallurgical industry, agriculture, motor vehicles, among others (Covarrubias and Cabriales, 2017). MPs constitute a group of elements with very heterogeneous physical, chemical and biological characteristics (González *et al*., 2017). MP are considered to be those elements consisting of a density greater than 5 g cm^{-3}, are classified as essential and non-essential, the latter do not have biological function and their presence can be toxic, while the essentials are required by all organisms in trace amounts (González *et al*., 2017).

MPs are generally found as natural components of the Earth’s crust, in the form of minerals, salts or other compounds, these cannot be degraded or easily destroyed naturally or biologically, as they do not have specific metabolic functions for living beings (Hernández *et al*., 2017). MPs are generally found in low concentrations in the environment, although, as a result of anthropogenic activities, their levels have increased (Liu *et al*., 2018), causing pollution in ecosystems exposed to them.

These MPs are risky because they are linked to several human health problems such as gastrointestinal cancer, damage to the immune system, mental damage and malnutrition, among others (Kumar *et al*., 2019). For the rehabilitation or restoration of ecosystems by MP contamination, it is necessary to know their destination, as well as the intensity, since alternatives of the use of particular biological methods can be implemented, this results in vegetation being used in cities as biological indicators or as monitors of specific pollutants (Turkyilmaz *et al*., 2018).

Urban development in the city of Saltillo has increased considerably, it has the highest number of inhabitants (807 537), the highest number of private dwellings inhabited (213 329) and the highest annual average growth rate (2.3%) of the state of Coahuila (INEGI, 2015). In the municipality, the industrial expansion is observed, among which those of automotive assembly, auto parts and manufacturing stand out (Mendoza, 2001), as well as the commercial and services activities that take place in the city, which has led to an increase in environmental pollution of the municipality (SEMA, 2017).

The inventory of pollutant emissions into the atmosphere is a strategic instrument for air quality management that allows to know the type and quantity of pollutants that are emitted into the air by the different sectors or categories. In this way Thus, an air quality monitoring is established in the municipality of Saltillo by SEMA in 2017, where the main anthropogenic pollutants per PM10 are unpaved roads 63.14%, paved roads 9.34%, metallurgical industry (includes steel) 8.8%, brick manufacturers 4.47%, vehicle> 3 t and tracto-trailers 3.02%, metal industry 2.94%, and those for PM 2.5 are unpaved roads 39.63%, metallurgical industry (includes steel) 16.98%, brick manufacturers 10.71%, vehicle> 3 t and truck-trailer 7.28%, paved roads 5.86% and metal industry 5.72% (SEMA, 2017). The objective of this work was to analyze the concentration of heavy metals (Cd, Cr, Pb and V) in the leaves of tree species in the city; determine their concentrations and compare them with toxicity limits in plant species, as well as determine the area of the highest concentration in the city of Saltillo, Coahuila.

Materials and methods

The study was carried out in the city of Saltillo, where samples were taken from different points distributed according to the structure of the city, seeking to have approximately 1 km distance between each point. 15 sampling points were established, of which 13 were distributed within the city of Saltillo and two points outside the urban area considered as control (Figure 1). The sampled plant species are the most representative tree species in the city and were *Pinus halepensis*, *Cupressus sempervirens* and *Prosopis glandulosa*, which showed wide distribution in the city.

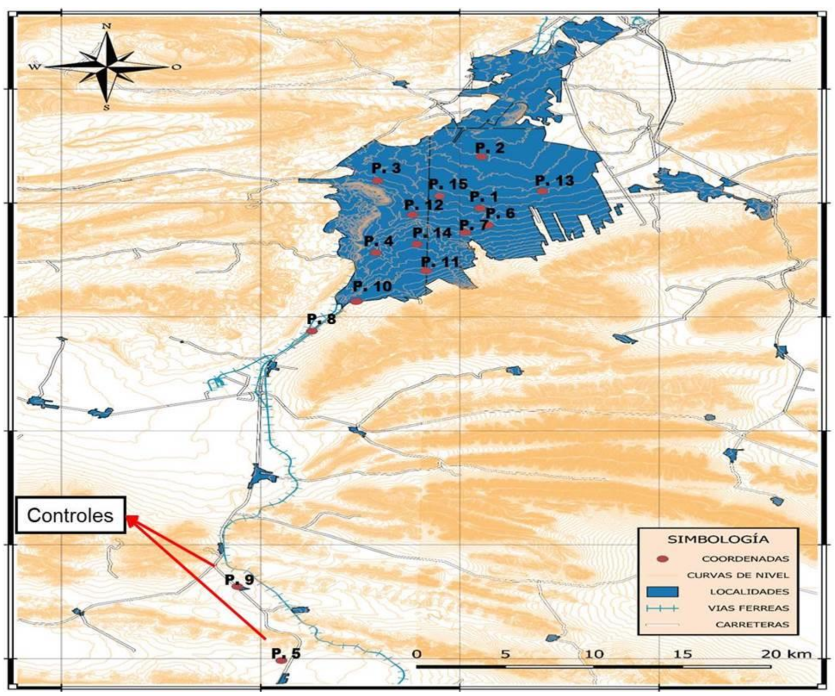

Figure 1. Area of study and distribution of sampling points.

100 g of foliar material taken at 2.5 m high was collected, it was washed with distilled water several times and then with deionized water. The samples were dried in a drying oven at a constant temperature of 80 °C until they reached a constant weight. 2 g of macerated sample was taken and placed in a muffle at a temperature of 600 °C for 3 h. Once the ashes had been obtained, digestion was performed with 10 ml of HCL and HNO_3 (in proportion 1:3) in electric grill for 15-20 minutes.

The sample was measured at 25 ml with deionized water and then filtered with Wathman paper #41 to perform the analysis of elements. The determination of heavy metals was carried out through an inductively coupled plasma optical emission spectroscopy equipment (ICP-OES), Model Varian 730-ES.

Results and discussion

According to the results obtained from the MP analyses (Cd, Cr, Pb and V) in the leaves of the selected tree species, it could be observed that the only point with the presence of Cd was 4 (54.57 µg g^{-1}) in species *C. sempervirens* (Figure 2). For the Cr, the species with the highest content was *P. halepensis* at points 2 (60.52 µg g^{-1}), 3 (75.74 µg g^{-1}), 6 (68.6 µg g^{-1}), 10 (76.95 µg g^{-1}), 11 (54.21 µg g^{-1}), 12 (64.33 µg g^{-1}), 13 (57.53 µg g^{-1}), 14 (54.46 µg g^{-1}) and 15 (74.03 µg g^{-1}). Species *C. sempervirens* had high concentration in points 3 (63.34 µg g^{-1}), 4 (129.29 µg g^{-1}), 12 (76.28 µg g^{-1}) and 15 (63.93 µg g^{-1}) and *Prosopis* spp., only in point 12 (69.87 µg g^{-1}) (Figure 3).

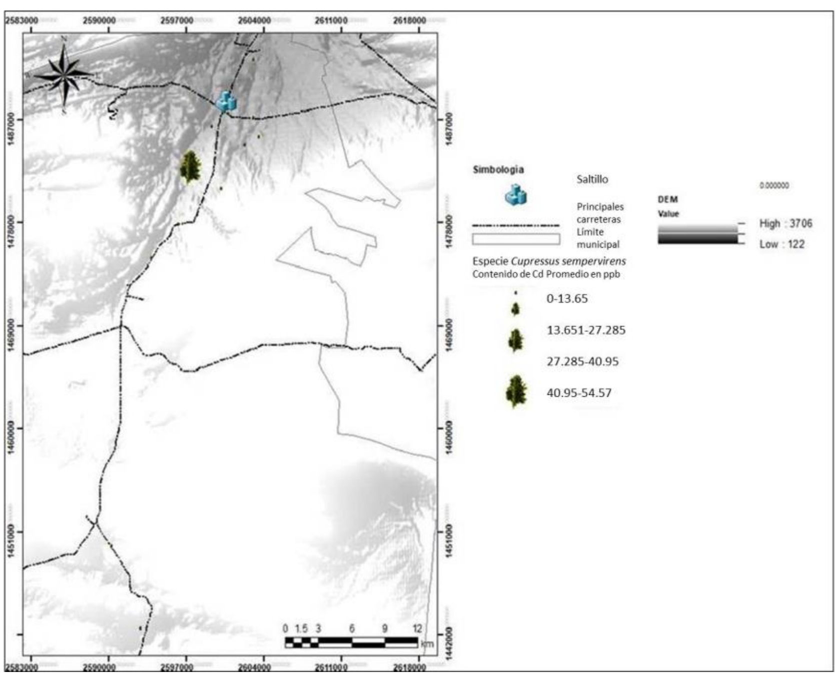

Figure 2. Cadmium content (Cd) at the different sampling points evaluated.

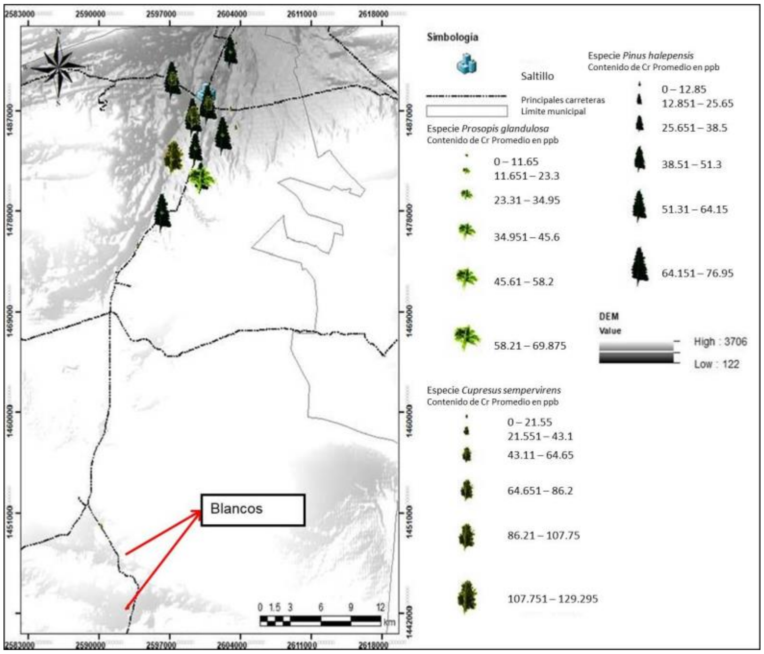

Figure 3. Chromium content (Cr) at the different sampling points evaluated.

The Pb was found only at points 4 (783.67 µg g^{-1}) and 15 (119.54 µg g^{-1}) in species *C. serpenvirens* and in point 2 (138.26 g^{-1}) in *Prosopis* spp. (Figure 4). The concentration of V was higher in the species *C. sempervirens* at points 3 (59.48 µg g^{-1}) and 4 (115.99 µg g^{-1}). *Pinus halepensis* presented V only at point 14 (51.92 µg g^{-1}). *Prosopis* spp. only in point 4 (54.23 µg g^{-1}) (Figure 5).

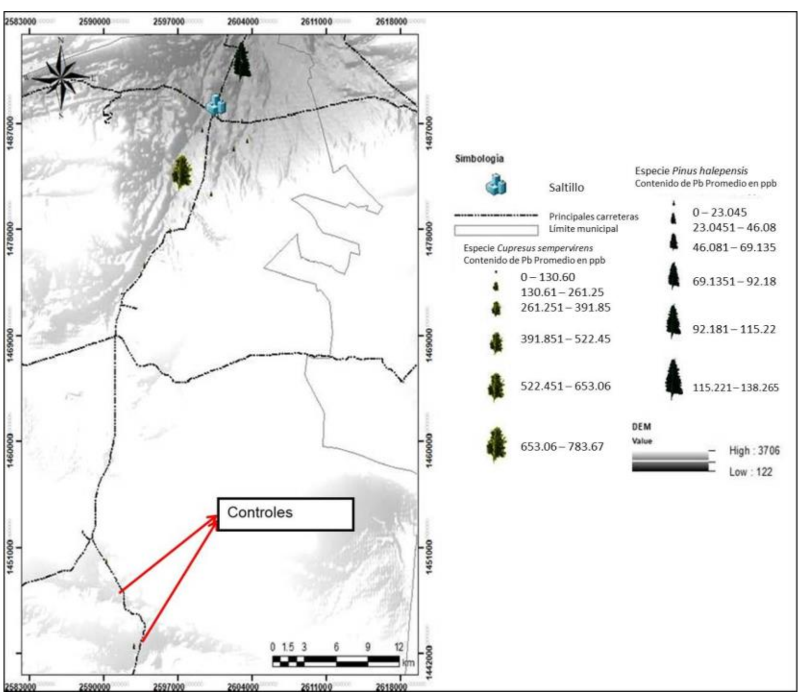

Figure 4. Lead content (Pb) at the different sampling points evaluated.

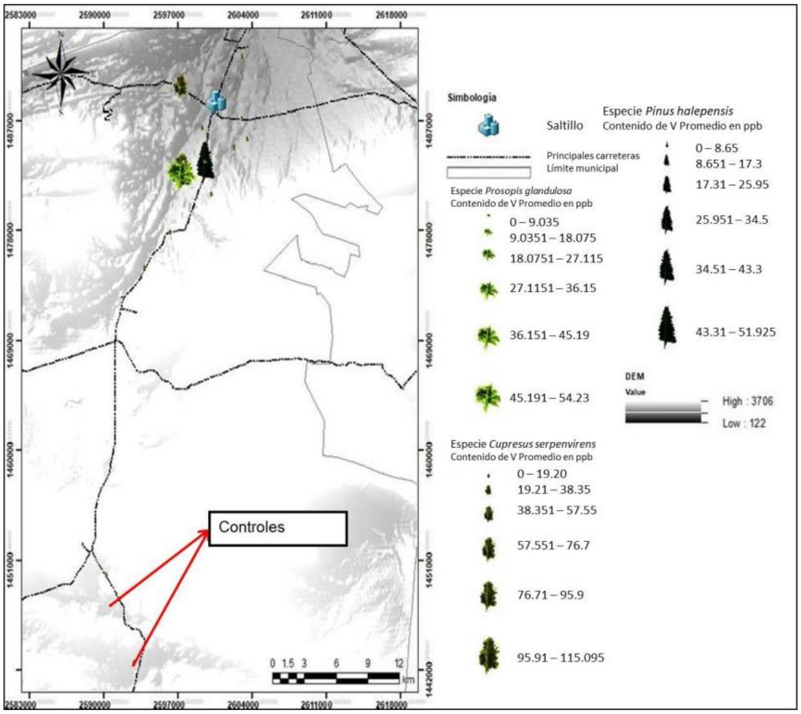

Figure 5. Vanadium content (V) at the different sampling points evaluated.

According to the results, species *C. sempervirens* was the one with the highest concentration of Cd, Pb and V, while *P. halepensis* was the one with the highest concentration of Cr. This shows that evergreen species can concentrate heavy metals. Checkpoints did not show any concentration of heavy metals, unlike points located in the city.

Nowadays, urban environments can represent greater exposure of MP pollution than dusty sites (Alcalá *et al*., 2012) and those industrial areas have a marked influence of these pollutants in cities (Aragón-Piña *et al*., 2006). The municipality of Ramos Arizpe has one of the most important and large industrial areas of the state of Coahuila (Mendoza, 2001). So, such an industry may be contributing some pollutants that may be being swept away by wind direction and held in some points in the city of Saltillo.

Research by Herrera-Márquez (2002) reported, in his study of water quality along the ‘Arroyo del Pueblo’ in the city of Saltillo, average Pb concentrations of 20 μg L^{-1} (winter period). While in the present research values of 783.67 μg g^{-1} (point 4) and 119.54 μg g^{-1} (point 15) were found in species *C. serpenvirens* and 138.26 μg g^{-1} (point 2) in *Prosopis* spp., for this element.

Authors such as Ramírez-Leal (1986) report that, by analyzing high-volume samples, during 1984 the main concentrations of lead (0.217 μg m^{-3}) and chromium (0.029 μg m^{-3}) were in March and those of cadmium (0.037 μg m^{-3}) were in October. During 1985 the highest values of cadmium (0.032 μg m^{-3}) were recorded in October, those of lead (0.13 μg m^{-3}) in July (63.69 μg m^{-3}) and those of chromium (0.155 μg m^{-3}) in April. This may indicate that there is variation of heavy metals depending on the season, as there are several conditions that determine the concentrations of these elements over time.

Tree vegetation, in addition to make city settings beautiful, improves air quality significantly, as it removes particles suspended in the environment, which is an important ecological service. The contaminant retention capacity in their crowns can be used as an environmental quality indicator (Astorga-Bustillos *et al*., 2011).

In this regard, there are several research papers with different types of plants and it has been determined that fasciculate pine leaves are the most used material, along with mosses, for this purpose (Piccardo *et al*., 2005), among the pine species with which studies of environmental biomonitoring by pollutants have been performed are *P. sylvestris* (Shcherbenko *et al*., 2008), *P. (Kord et al*., 2010), *P. halepensis* (Astorga-Bustillos *et al*., 2011), *P. pinea* (Rucandio *et al*., 2011). However, Cupressaceae have also proven to be bioindicator species of environmental pollution, some of the species that have been worked with are *Cupressus arizonica* (Alcalá *et al*., 2008) and *C. sempervirens* (Rucandio *et al*., 2011).

One advantage of conifers over broad-leaf species (deciduous leaves) is that they accumulate atmospheric pollutants for several years as they are evergreens species (Di Guardo *et al*., 2003). However, although evergreen species are useful for this purpose, the quantitative interpretation of the data is complicated by the lack of comparative studies (Hellström *et al*., 2004).

Conclusions

The southeast and central areas of the city of Saltillo have the highest concentrations of the MP analyzed (Cd, Cr, Pb and V). The species *Cupressus sempervirens* was the one with the highest concentration of Cd, Pb and V, while the species *Pinus halepensis* was the higher in Cr. This shows that perennial species can accumulate heavy metals in foliar tissue, indicating that they can be used as species for heavy metal contamination biomonitoring.

The control points did not present any concentration level of the heavy metals analyzed, which shows that in the city of Saltillo there may be sources of pollutants that cause some of these elements to appear.

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