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Characterization of environmental ultrafine particles in the metropolitan area of Guadalajara

Caracterización de partículas ultrafinas ambientales en el área metropolitana de Guadalajara

PEÑA-GARCÍA, Laura†*, ROSAS-ELGUERA, José and MACIEL-FLORES, Roberto

Universidad de Guadalajara. Centro Universitario de Ciencias Biológicas y Agropecuarias. Camino Ramón Padilla Sánchez 2100, Nextipac, 44600 Zapopan, Jal.

ID 1st Autor: *Laura, Peña-García* / **ORC ID:** 0000-0002-9008-133, **Researcher ID Thomson:** U-4752-2018, **CVU CONAHCYT ID:** 311129

ID 1st Co-author: *José, Rosas-Elguera* / **CVU CONAHCYT ID:** 10786

ID 2nd Co-author: *Roberto, Maciel-Flores* / **ORC ID:** 0000-0002-3540-860X, **CVU CONACYT ID:** 206469

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Abstract

The leaves of *Ficus benjamina*, by demonstrating a high capacity to accumulate metals, emerge as promising bioindicators of environmental particles. The application of various analysis techniques, including SEM and XRF, facilitated the observation, identification and confirmation of the presence of 21 metallic elements, one non-metal (Br) and two radioactive elements (Ac and Th) in the samples. This study highlights the polluting potential in urban areas, shedding light on environmental quality. Furthermore, the similarity between the metallic particles found in the samples and those present in lung tissue and soil highlights risks to human health associated with exposure to particulate matter. These findings contribute significantly to the understanding of environmental health in urban environments. Objectives: Identify and characterize elements in *Ficus benjamina* leaves, soil and lung tissue. Methodology: The samples of leaves and lung tissue were analyzed by Scanning Electron Microscopy, the leaf samples were also applied Atomic Absorption Spectroscopy and the Multi-Elemental Analysis by X-ray Fluorescence technique was applied to the soil. Contribution: A comparative table was obtained of the elements found in both samples and what uses they have in daily life.

Ultrafine particles, Guadalajara Metropolitan Area, Pollution

Resumen

Las hojas de *Ficus benjamina*, al demostrar una alta capacidad para acumular metales, surgen como prometedores bioindicadores de partículas ambientales. La aplicación de diversas técnicas de análisis, incluyendo SEM y XRF, facilitó la observación, identificación y confirmación de la presencia de 21 elementos metálicos, un no metal (Br) y dos elementos radioactivos (Ac y Th) en las muestras. Este estudio destaca el potencial contaminante en zonas urbanas, arrojando luz sobre la calidad ambiental. Además, la semejanza entre las partículas metálicas halladas en las muestras y las presentes en tejido pulmonar y suelo subraya riesgos para la salud humana asociados con la exposición a material particulado. Estos hallazgos contribuyen significativamente a la comprensión de la salud ambiental en entornos urbanos.Objetivos: Identificar y caracterizar elementos en hojas de *Ficus benjamina*, suelo y tejido pulmonar.Metodología: Las muestras de hojas y tejido pulmonar se analizaron mediante Microscopía electrónica de barrido, las muestras de hojas también se les aplicó Espectroscopia de absorción atómica y al suelo se le aplicó la técnica de Análisis multielemental por fluorescencia de rayos X. Contribución: Se obtuvo una tabla comparativa de los elementos encontrados en las muestras y asocio con los usos que tienen en la vida cotidiana.

Partículas ultrafinas, Zona Metropolitana de Guadalajara, Contaminación

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† Researcher contributed as first author.

Introduction

Air pollution can contribute to various diseases and aggravate pre-existing conditions, taking into consideration that PAHO (2018) said that "nine out of ten people are now breathing polluted air, which kills 7 million people each year" (PAHO/WHO, 2018). Exposure to air pollution can trigger or exacerbate respiratory diseases such as asthma, chronic bronchitis, chronic obstructive pulmonary disease (COPD), currently the third leading cause of death in the world (WHO, 2023) and acute respiratory infections (How Air Pollution Is Destroying Our Health [WHO], 2023). Particulate matter and pollutants in the air can irritate the lungs and cause shortness of breath, coughing, wheezing and other respiratory symptoms. It is also associated with an increased risk of cardiovascular diseases, such as heart disease, high blood pressure, stroke and diseases of the circulatory system (Albright et al., 2012).

It is known that air pollution can cause health problems, especially long-term exposure to fine particulate matter (PM2.5), which can come from sources such as vehicles and burning of various materials that impact the health of the population (EPA, 2023). Studies by (Riojas-Rodriguez et al., 2014) report that there is a relationship between air pollution by 10 µm particles and cardiovascular diseases, respiratory problems and even morbidity in people over 65 years of age. Lepeule et al. in 2012, Raaschou-Nielsen et al. in 2013 and López-Cima et al. in 2011, support the idea that air pollution, in particular exposure to fine particulate matter (PM2.5), is associated with an increased risk of developing lung diseases and other health problems. These epidemiological studies have found significant links between chronic exposure to particulate pollution and a range of health conditions.

Development

Air quality in Jalisco, as in other parts of Mexico, can be affected by several factors, such as industrial activity, vehicular traffic, climatic conditions and agricultural practices. In Jalisco, air quality is monitored through several monitoring stations distributed throughout the state. Indices such as the Metropolitan Air Quality Index (IMECA) and the Air Quality Index (ICA) are used to assess and communicate air quality to the population.

These indices classify air quality at different levels, from "good" to "very bad", based on the levels of pollutants present in the air, such as suspended particulate matter (PM10 and $PM_{2.5}$), sulphur dioxide (SO_2), nitrogen dioxide (NO2) and ozone (O_3).

The main air pollutants in Jalisco are usually suspended particulate matter, ozone and nitrogen dioxide. Suspended particulate matter can come from a variety of sources, including fossil fuel combustion, industrial emissions and agricultural activities. Ozone is formed due to the chemical reaction of polluting gases in the presence of solar radiation. Nitrogen dioxide is emitted mainly by vehicles and some industrial sources (Figure 1).

Air quality in the MCMA can vary throughout the year. During the dry season and in the spring and summer months, when there are stable weather conditions and higher solar radiation, it is more common to observe elevated levels of ozone and suspended particulate matter. These times can be of particular concern for people with respiratory and cardiovascular diseases, as well as for the most vulnerable groups, such as children and older adults.

Figure 1 Panoramic view of the west from Periférico Sur and the road to ITESO of the ZMG

The Guadalajara Metropolitan Area (ZMG) is one of the largest and most populated urban areas in Mexico. Due to its high population density, industrial activity and vehicular traffic, air pollution is a significant challenge in this region.

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Some areas have significantly increased vehicular traffic, in the city we have six avenues that stand out for their exponential growth rate, these are: López Mateos, Tonaltecas, Mariano Otero, Juan Gil Preciado, Carretera a Colotlán and Carretera a Chapala. According to IMEPLAN (Instituto de Planeación y Gestión del Desarrollo del área Metropolitana de Guadalajara) (figure 2), the following are some of the most important urban areas in Guadalajara.).

Figure 2 Avenues with the most vehicular traffic in the ZMG
Source: (Vialidad: Seis avenidas encabezan el caos en Guadalajara | El Informador, 2023)

Suspended particulate matter, such as PM10 and PM2.5, is one of the main pollutants in the MCMA. These particles are emitted by vehicles, industrial sources, construction and agricultural activities. Inhalation of fine particles can have adverse health effects, especially on the respiratory system. The ZMG is home to a variety of industries that emit air pollutants, such as toxic gases and particulate matter. In addition, the high number of vehicles on the road contributes significantly to the emission of gaseous pollutants, including nitrogen oxides (NOx) and carbon dioxide (CO2), which increases annually in the MCMA (Table 1). Vehicle emissions are particularly problematic at peak hours and in areas with traffic congestion.

Municipality	2019	2020	2021	2022
Guadalajara	982,470	1,001,932	1,016,136	1,042,028
El Salto	58,007	61,095	64,730	69,475
Tlajomulco de Zúñiga	162,542	171,910	184,077	197,609
San Pedro Tlaquepaque	256,376	265,044	275,499	290,179
Tonalá	187,753	195,635	206,457	219,324
Zapopan	788,066	803,237	825,645	852,549
Total, anual	2,435,214	2,498,853	2,572,544	2,671,164

Table 1 Registered motor vehicles in circulation
Source: (INEGI, 2022)

As one of the most populated municipalities in the ZMG, Zapopan has also recorded high levels of air pollution in certain areas. The combination of vehicular traffic and industrial development has been a major source of pollutant emissions. Tlaquepaque has faced similar air quality challenges, as it is also home to a significant amount of industrial activity and considerable population density. And Tonalá is another municipality in the ZMG that has registered air pollution problems. In addition to the influence of vehicular traffic and industry, waste burning and artisanal activity have also contributed to the emission of pollutants.

In addition to the emission of these particles, quarries and brick kilns also emit volatile organic compounds, such as hydrocarbons, which can be toxic to the environment. These compounds are responsible for the formation of smog, a form of air pollution that affects human health and the environment.

A person's distance from a major road can influence their exposure to airborne pollutants. As we move closer to a road with high vehicle traffic or other sources of emissions, the concentration of particulate matter is likely to be higher, which could increase the risk of developing diseases associated with air pollution. However, it is important to keep in mind that air pollution is a complex and multifactorial problem, and distance to a major roadway is not the only determinant of exposure and health risks (Peña, 2019).

Air pollution has been considered an environmental threat by the World Health Organization (World Health Organization (WHO), 2021). Air pollution can be considered as the modification of the atmosphere by the discharge of elements in high concentrations in certain periods of time, which negatively affects any living organism or component of the ecosystem. Atmospheric pollutants can be transported over long distances before reaching the final receptor and depending on the doses, can seriously affect human health and vegetation. The residence time and dispersion of pollutants emitted to the atmosphere by natural or anthropogenic sources depends on meteorological factors such as temperature, wind direction and speed, relative humidity, solar radiation, as well as topographical factors.

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The most common air pollutants are suspended particles whose components include heavy metals, nitrates and sulphates, among others (Pérez et. al. 2006).

Description of the method

A methodology was designed for the collection of environmental samples using a grid designed every two kilometres in the ZMG, which was based on the methodological proposal of Bautista (Bautista et. al., 2011). A total of 155 samples of Ficus benjamina leaves were collected and, thanks to an agreement with the Instituto Jalisciense de Ciencias Forenses (IJCF) specifically for this work, we were able to observe samples of the main bronchi, first branches or pulmonary alveoli using the SEM technique, observing elements present in 12 samples of lung tissue. The samples were stored in their facilities and preserved in 2% glutaraldehyde in 1.5 ml Eppendorf tubes. The samples were critically desiccated with a Samdri 795 Tousimis.

The equipment used for the observation of the samples by EDS was a Jeol JSM 6610LV, operating at 10kV, with an Oxford Xmax EDS detector and Oxford AZtec software. Scanning electron microscope observation was performed with a secondary electron detector.

For the extraction of heavy metals by AA, Ficus benjamina leaf samples were taken to the laboratory and acid digestion was performed. The samples were homogenised beforehand. The determination was carried out in an atomic absorption spectrophotometer model Varian AA 240 FS, with a CZERNY-TURNER design monochromator, 4-lamp panel and inert and adjustable spray chamber. The technique used was flame technique and calibration curves were used. All samples were treated in duplicate. The elements analysed were Cd, Co, Cr, Cu, Ni, Pb and Zn with detection limits in ppb. The curve starts at zero, which is distilled water, thus calibrating the equipment for each element. The ranges represent the concentration used in the first and last standard to form the curve.

A qualitative elemental chemical analysis of elements between fluorine (F) and uranium (U) in collected soil samples was performed using the X-ray fluorescence multi-elemental analysis (XRF) technique. A PHILIPS 2400 spectrometer with automatic tablet exchanger PW2510 was used for the XRF analysis. The samples were processed in the pressed powder mode at room temperature. For the preparation of the samples, it was necessary to pass them through a three-ball mill (Retsch brand) to homogenise the texture of the samples. This allowed to obtain a particle size smaller than 0.001 mm in diameter, in order to avoid that, once the particles were pressed, they would not detach from the tablets.

A "Specac" manual press was used to prepare the tablets. For the preparation of the tablets, 10 g of boric acid were initially pressed into containers at three tonnes for three minutes, which left a hole in the centre in which 2 g of soil sample were deposited, to be pressed again and given a final finish with a material called "Mylard", which is used for reading samples characterised by dry powder with a very fine particle size. Finally, the samples were labelled.

XRF elemental analysis of soil samples was carried out using X-rays from a rhodium lamp operating at 24 KV. Five scanning procedures were performed on each sample using different fluorescence detector crystals and collimator, as well as the energy intensity for each scan. The analysis conditions of the elements of the periodic table were considered. Once the elemental composition results of the soil samples were obtained, the SuperQ software of the spectrometer was used and a qualitative analysis of the elements was performed.

The elements identified are shown in a comparative table and some of their main applications or uses.

Results

Some of the elements identified were matched and their uses were analyzed

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Thirty-four elements were found in the samples, five of them, Cu, Cr, Ni, Pb and Zn were found in all sample analyses. The use of these metals is very representative in the automotive industry, Cr is used in some agricultural products, Zn is important in the electrical industry, pharmaceuticals and in the manufacture of lamps. Cu and Cr in excess are toxic and Pb is also harmful to health, so its use has decreased, however, it still has applications in several areas. Excess Zn is classified as carcinogenic and Ni in some cases can cause cancer or allergies.

Cadmium (Cd) was found in lung tissue and leaves and its compounds are used in the manufacture of various types of batteries, among many other uses. Cd is carcinogenic and teratogenic. The elements As, Nb, Os and Re were present in soil (XRF) and lung (SEM). The applications of these elements are related to the electrical industry (in various fields). Os can be found as an impurity in minerals of basaltic origin together with Ir, Rh and Fe. As mentioned above, Nb, Os and Re have the potential to cause lung problems, and the latter two can also cause skin and eye damage. According to Utsunomiya et al., (2004) the presence of As in the samples suggests that it comes from anthropogenic sources such as fossil fuel combustion, power plants and waste incinerators.

Ca and K were observed by XRF in soil and SEM in leaves, they are generally mineral constituents, and only K40 may be a natural cause of genetic mutation.

If was identified by SEM in leaves and lung (SEM). And commonly Si and Nb (SEM) in lung (SEM) are used for glass making (among other uses).

Individually, Ir and Pt are used in the automotive industry for spark plugs, as well as Pd, however, the latter is used for spark plugs, but in aircraft. The elements Pd, Pt and Rh have applications in the production of vehicle catalytic converters.

As regards radioactive elements, the presence of La, Ac and Th was identified. Lanthanum (La) is used in fluorescent and energy-saving lamps, televisions, among other uses. Actinium (Ac) is mainly used in medicine for radiotherapy and research. Thorium (Th) is considered an industrial catalyst, used in medicine and as a source of nuclear energy.

All three are hazardous to health, can cause various types of cancer and lung problems among others.

SOIL XRF	SHEETS AA	SHEETS SEM	LUNG SEM	USES	Health effects
Br				In agricultural chemicals, dyes, insecticides, pharmaceuticals and many other uses as new uses continue to be found, despite its toxicity.	It has an irritant effect on the eyes and throat and produces painful sores when it comes into contact with the skin.
			Ag	To make mirrors, it is the best known visible light reflector. In dental alloys, welding, electrical contacts and batteries. It has antibacterial properties, and silver nanoparticles are applied to clothing to prevent bacteria from digesting sweat and forming unpleasant odours. Silver threads are woven into the fingertips of gloves so that they can be used on touch screens.	Chronic ingestion or inhalation of silver compounds can lead to a condition known as argyria, which produces a greyish pigmentation of the skin and mucous membranes. Silver has antibacterial properties and can kill lower organisms quite effectively.
			Al	In cans, foils, kitchen utensils, window frames, beer kegs and aircraft parts.	It can accumulate in the body and a link to Alzheimer's disease has been suggested, but not proven.
Ga				Obtained in small quantities from minerals such as Al and Zn. Used in the construction of integrated circuits, Blu-ray technology, mobile phones, blue and green LEDs and pressure sensors for touch switches. It is mainly produced as a by-product of zinc refining.	It is non-toxic although some gallium compounds can be very dangerous, e.g. high exposures to gallium chloride can cause throat irritation, respiratory distress, chest pain and vapours can cause pulmonary oedema and partial paralysis.
As			As	Wood preservation, insecticide, herbicide,	In small doses it is toxic and is a suspected carcinogen. Some

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				pigments and in pyrotechnics and as a decolouriser, as well as in the construction of laser diodes and LEDs. And as gallium arsenide as a semiconductor material used in circuits.	foods, such as prawns, contain a surprising amount of arsenic in an organic form that is not very harmful.
Ca		Ca		As a reducing agent in the preparation of metals such as thorium and uranium. Also alloyed with aluminium, beryllium, copper, lead and magnesium. Large deposits of limestone are used for construction and cement production. As a soil improver and in water treatment to reduce acidity, in the chemical industry, in steel making to remove impurities and in medicine to immobilise.	Essential for all living things.
	Cd	Cd	Cd	In rechargeable nickel-cadmium batteries, although it is gradually being replaced by nickel-metal hydride batteries. For electroplating steel, protecting aircraft components and oil rigs. Cadmium absorbs neutrons and is therefore used in rods in nuclear reactors.	It is toxic, carcinogenic and teratogenic (disrupts the development of an embryo or foetus).
Co	Co	Co		It can be magnetised and is used to make magnets, in alloys for jet turbines and gas turbine generators (high temperature resistant), in electroplating, to produce bright blue paint, porcelain, glass, ceramics and enamels.	Radioactive cobalt-60 is widely used in cancer treatment.
Cr	Cr	Cr	Cr	Chrome-plated car and truck parts, for hardening steel, stainless steel fabrication, leather tanning,	It is an essential trace element for humans, helping to utilise glucose, but is poisonous in excess.
				industrial catalysts and pigments (in bright green, yellow, red and orange).	
Cu	Cu	Cu	Cu	Agricultural products, car and truck components, mainly radiators (high thermal conductivity and corrosion resistance), brakes and bearings, as well as cables and electric motors. A car contains between 20 and 45 kg; in traditional trains between one and two tonnes, and up to four tonnes in high-speed trains. Up to 10 tonnes of copper per kilometre are used in catenaries on high-speed lines. In chemical tests for sugar detection.	It is an essential element, but is toxic in excess.
Fe			Fe	Indispensable in the construction of automobiles, ships and structural components of buildings. Also in the manufacture of magnets, dyes (polishing pigments among others) and abrasives. Production of structural steels, cast iron and wrought iron.	It can cause conjunctivitis, chorioretinitis and retinitis. Chronic inhalation of excessive concentrations of iron oxide fumes or dusts may result in the development of benign pneumoconiosis (siderosis). Inhalation of excessive concentrations of iron oxide may increase the risk of developing lung cancer.
			Hf	Gas and incandescent lamps, catalysts, oxygen and nitrogen removal from vacuum tubes. Hafnium oxide is used as an electrical insulator in microchips and hafnium catalysts have been used in polymerisation reactions.	It has no known biological role and has low toxicity.
			Hg	In the chemical industry as catalysts. It is also used in some electrical switches and rectifiers. All other uses have been eliminated due to toxicity.	Damage to the nervous system, DNA and chromosomes, allergic reactions, degradation of brain function, personality changes, tremors, vision changes, deafness and even memory loss.

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			Ir	Highly resistant to corrosion. In spark plug contacts due to its high melting point and low reactivity; osmium-iridium alloys are used in compasses and scales, long-life parts in aircraft engines and high-temperature crucibles.	Eye or gastrointestinal irritation with low hazard if ingested. Low toxicity.
K		K	K	The greatest demand is in fertilisers. Many other potassium salts are of great importance, including nitrate, carbonate, chloride, bromide, cyanide and sulphate. Carbonate is used in the manufacture of glass. Hydroxide in pharmaceuticals and in salt drops.	Essential for life. Important to maintain fluid and electrolyte balance. The naturally occurring potassium-40 isotope is radioactive and, although this radioactivity is mild, it may be a natural cause of genetic mutation in humans.
Mn				Essential for steel and iron production, most aluminium beverage cans contain 0.8-1.5 %; glass and ceramics are coloured with various Mn compounds.	It is one of the three essential toxic trace elements, meaning that it is not only necessary for human survival, but is also toxic when present in high concentrations.
			Mo	Most molybdenum is used to make alloys, with steel used in engine parts. Other alloys are used in heating elements, drills and saw blades. Molybdenum disulphide is used as a lubricant additive. Other uses for molybdenum include catalysts for the petroleum industry, inks for circuit boards, pigments and electrodes.	In animals, molybdenum and its compounds are highly toxic, there is evidence of liver dysfunction with hyperbilirubinaemia.
Nb			Nb	Alloys are used in jet and rocket engines, building beams, oil rigs, oil and gas pipelines. It has superconducting properties. It is used in superconducting magnets for particle accelerators and in scanners. Niobium oxide compounds are added to glass to increase the refractive index, allowing corrective lenses to be thinner.	When inhaled, it is retained mainly in the lungs, but secondarily in the bones. It interferes with calcium as an activator of the enzyme system.
Ni	Ni	Ni	Ni	In chrome-plating machines as it resists corrosion, it is used in toasters and electric ovens. In copper-nickel alloys in desalination plants, steel and nickel for shielding. Other nickel alloys are used in ship propeller shafts and turbine blades. In batteries, including rechargeable nickel-cadmium and nickel-metal hydride batteries used in hybrid vehicles. As a catalyst for hydrogenating vegetable oils.	Some nickel compounds can cause cancer if the dust is inhaled and some people are allergic to contact with the metal.
Os			Os	Used to produce very hard alloys for pen tips, instrument pins, needles and electrical contacts. Also used in the chemical industry as a catalyst.	It is a non-toxic metal, but in oxide form it is volatile and highly toxic, causing lung, skin and eye damage.
			Pd	In catalytic converters, in jewellery, dentistry, watchmaking, in test strips for testing blood sugar levels, in aircraft spark plugs, in the production of surgical instruments; also in the electronics industry in ceramic capacitors found in laptops and mobile phones. These consist of layers of palladium sandwiched between layers of ceramic.	May cause irritation or hypersensitivity of the skin, eyes or respiratory tract. If liquid is present, it may cause burns to the skin and eyes.
			Pt	In jewellery, catalytic converters, fibre optics and LCD manufacturing, turbine blades, spark plugs,	Platinum as a metal is non-toxic, but salts may cause DNA alteration, cancer, allergic reactions of skin and mucous membranes,

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				pacemakers and dental fillings, in chemotherapy drugs. In the chemical industry as a catalyst for the production of nitric acid, silicon and benzene. In the electronics industry for hard disks and thermocouples.	damage to intestine, kidneys and bone marrow, as well as hearing damage.
Re			Re	As an additive for tungsten and molybdenum based alloys, used for furnace filaments and X-ray machines. Also used as an electrical contact material. Also in nickel alloys to make single crystal turbine blades.	Potential health effects: Eye irritation, skin irritation. Liquid may cause burns to skin and eyes. Ingestion: May cause respiratory tract irritation.
			Rh	In catalytic converters for automobiles. Catalyst in the chemical industry, to produce nitric acid, acetic acid and hydrogenation reactions. Used for coating optical fibres and optical mirrors, and for crucibles, thermocouple elements and headlight reflectors, as well as electrical contact material as it has a low electrical resistance and is highly resistant to corrosion.	All rhodium compounds should be considered highly toxic and carcinogenic.
		Ta	Ta	In the production of electronic components, in portable electronic devices such as mobile phones. The alloys can be extremely strong and have been used for turbine blades (rotodynamic fluid machine), rocket nozzles and nose caps for supersonic aircraft.	It does not cause an immune response in mammals, so it is widely used in the manufacture of surgical implants. It can replace bone, for example, in skull plates; as foil or wire connecting torn nerves; and as woven gauze (attaches to abdominal muscle).
Ti			Ti	Alloying agent with metals such as aluminium, molybdenum and iron. Mainly used in aircraft, spacecraft and missiles. Also for making golf clubs, laptops, bicycles and crutches. Excellent resistance to corrosion in seawater, used in desalination plants, to protect ship hulls, submarines and in general structures exposed to seawater. In (hip) joint replacements and dental implants. As titanium oxide, it is used as a pigment in house paints, artists' paints, plastics, enamels and paper. Good reflector of infrared radiation, it is used in solar observatories where heat causes poor visibility. Also in sunscreens.	It is non-toxic, although fine titanium dioxide dust is carcinogenic.

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V				About 80% of the vanadium produced is used as a steel additive. Vanadium-steel alloys are very strong and are used for armour plates, shafts, tools, piston rods and crankshafts. Less than 1% vanadium makes the steel resistant to shock and vibration. Vanadium alloys are used in nuclear reactors because of vanadium's low neutron absorption properties. Vanadium oxide is used as a pigment for ceramics and glass, as a catalyst and to produce superconducting magnets.	It only causes health effects if consumed in excess, but when airborne it can cause bronchitis and pneumonia.
			W	Tungsten and its alloys are used as welding electrodes and heating elements in high-temperature furnaces. Tungsten carbide is considerably hard and very important for the metallurgical, mining and oil industries. In mixtures of tungsten and carbon powder they withstand up to 2200°C. As cutting and drilling tools, in "painless" dental drills it rotates at ultra-high speeds. Calcium and magnesium tungsten are used in fluorescent lighting.	In humans, exposure to tungsten has not been associated with specific health effects.
Zn	Zn	Zn	Zn	Galvanising metals such as iron. In car bodies, street lighting poles, safety barriers and suspension bridges. To produce die castings, important in the automotive, electrical and hardware industries. In alloys such as brass, nickel silver and aluminium brazing. Zinc oxide is widely used in the manufacture of paints, rubber, cosmetics, pharmaceuticals, plastics, inks, soaps, batteries, textiles and electrical equipment. Zinc sulphide to make luminous paints, fluorescent lights and X-ray screens.	Zinc may be carcinogenic in excess.
		Si	Si	To make aluminium-silicon and ferrosilicon alloys. For electrical generators and transformers, engine blocks, cylinder heads, machines, tools and for deoxidising steel. As a semiconductor in solid state devices in the computer and microelectronics industries. Sand (silica dioxide) and clay (aluminium silicate) are used to make concrete and cement. Sand is also the main ingredient in glass. Silicon, as a silicate, is present in ceramics, enamels and high-temperature ceramics. It is also used to make silicones. Silicone oil is added to some cosmetics and hair conditioners. As a sealant in bathrooms, windows, pipes and roofs.	Inhalation of crystalline silica dust may cause silicosis.

Pb	Pb	Pb	Pb	In automotive batteries, pigments, ammunition, cable sheathing, weightlifting, diving weight belts, lead crystal (leaded glass), radiation protection and in some solder. Other uses are for storage of corrosive liquids. It is also sometimes used in architecture, for roofing and in stained glass.	The use of this metal has been banned in many cases because it is harmful to health.
La				Manufacture of high quality lenses. In fluorescent lamps, energy saving lamps, televisions and glass. To produce catalysts.	It can accumulate in the body and cause serious health problems. It is toxic, teratogenic (disrupts the development of an embryo or foetus) and carcinogenic.
Ac				Actinium is a very powerful source of alpha rays, but is rarely used outside research. It is used in medicine, for the production of radiotherapy. It is found in natural uranium in the order of 0.175% and also naturally occurring.	It is dangerous in the workplace because it can be inhaled, which can cause pulmonary embolism; it can also damage the liver when it accumulates in the human body.
Th				Alloying agent with magnesium. As an industrial catalyst, source of nuclear energy. It is approximately three times more abundant than uranium and as abundant as lead.	Because it is extremely radioactive, ingestion of even small amounts can cause very severe damage. It is as dangerous as plutonium.

Table 2 Chemical composition of samples analysed by XRF, AA and SEM, uses and health effects
Source: (Peña García, 2019)

Conclusions

The leaves of *Ficus benjamina* have a great capacity to accumulate metals and can be used as bioindicators of environmental particles.

The diversity of techniques used for the analysis of the samples allowed us to first observe, then identify and finally corroborate the presence of metallic elements in the samples.

The SEM technique allowed us to observe the composition of the particles. By means of XRF we determined the presence of 21 elements, one non-metal Br and two radioactive elements Ac and Th.

The concentrations of the seven metals analysed were identified by AA, of which the most abundant were Cu and Pb.

This work provides a glimpse of the polluting potential in urban areas.

The similarity between the metal particles identified in the samples collected and those observed in lung tissue, warns of latent risks to human health from particulate matter.

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Applied Environmental Geosciences of the Universidad de Guadalajara**.**

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