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Journal of Experimental Systems

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Presentation of Content

In the first article we present, *Characterization of environmental ultrafine particles in the metropolitan area of Guadalajara*, by PEÑA-GARCÍA, Laura, ROSAS-ELGUERA, José and MACIEL-FLORES, Roberto, with adscription in the Universidad de Guadalajara; as next article we present, *Determination of drying costs to obtain parchment coffee in Oaxaca's Cañada region*, by GARCÍA-MAYORAL, Luis Eduardo, QUINTANAR-OLGUIN, Juan and MARTINEZ-RUIZ, Antonio, with adscription in the Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias; as next article we present, *Mangrove forests transition between land and ocean, bioremediation areas, refuge and conservation of species*, by VIZCAINO-RODRIGUEZ, Luz Adriana, RAVELERO-VAZQUEZ, Víctor, LUJAN-GODINEZ, Ramiro and CARO-BECERRA, Juan Luis, with adscription in the Universidad Politécnica de la Zona Metropolitana de Guadalajara and Instituto Tecnológico de Tlajomulco; as final article we present, *Study of spin coating variables for deposition of hole transport nanolayer used in hybrid perovskite solar cells*, by ERRO-QUIÑONEZ, José, MONTES-GUTIERREZ, Jorge, GARCIA-GUTIERREZ, Rafael and CONTRERAS-LOPEZ, Oscar, with adscription in the Universidad de Sonora and Universidad Nacional Autónoma de México.

Content

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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

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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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Determination of drying costs to obtain parchment coffee in Oaxaca's Cañada region

Determinación de los costos de secado para la obtención de café pergamino en la región de la Cañada de Oaxaca

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Abstract

One of the little studied technological components in coffee production is the drying process, it is the most difficult, and expensive operation, representing between 45 and 60% of the processing costs. In addition, is the stage that concentrates 49% of the time used in the benefited process. The central objective of drying the grain is to avoid its deterioration and preserve its quality during storage. This stage is critical and requires control, since, it is decisive for the organoleptic quality of the drink due to its direct impact on the quality sensory. The unit costs of drying one kg of washed coffee and transforming it into parchment coffee, for the 2023 harvest season, were on average; $35.91, 31.87 and 44.88, for the solar, traditional and african bed drying systems, respectively. The unit costs depend on the initial investment for the construction of the drying system: 69.6% in solar drying and 83.2% in the african bed system.

Dry kinetics, DDrying methods, Nutraceutical quality

Resumen

Uno de los componentes tecnológicos poco estudiados en la producción de café, es el proceso de secado. Es la operación más difícil y costosa, llegando a representar entre el 45 y 60% de los costos de procesamiento. Además, es la etapa que concentra el 49% del tiempo utilizado en el proceso de beneficiado. El objetivo central del secado del grano es evitar su deterioro y conservar su calidad durante el almacenamiento, esta etapa es crítica y requiere control, ya que, es determinante para la calidad organoléptica de la bebida por su repercusión directa en la calidad sensorial. Los costos unitarios de secar un kg de café lavado y transformarlo en café pergamino, para la temporada de cosecha 2023, fue en promedio; $35.91, 31.87 y 44.88, para los sistemas de secado solar, tradicional y camas africanas, respectivamente. Los costos unitarios dependen de la inversión inicial para la construcción del sistema de secado: 69.6% en el secado solar y 83.2% en el sistema de camas africanas.

Cinética de secado, Métodos de secado, Calidad nutraceutica

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Introduction

In Mexico, coffee growing is one of the most important crops in the agricultural sector, especially in rural communities. Production areas are concentrated in 12 states, mainly in small production units in mountainous areas, with the states of Chiapas, Veracruz, Puebla and Oaxaca accounting for 81.1% of national production (SIAP, 2022).

The process of transforming cherry coffee into parchment coffee is known as processing and begins with the cutting and harvesting of coffee cherries with an ideally homogeneous maturity until dry coffee is obtained, known as parchment coffee, since the bean is covered by an opaque yellow layer called parchment (Ortega, 2010).

One of the little studied technological components in coffee production is the drying process, which is the most difficult and costly operation, representing between 45 and 60% of processing costs. It is also the stage that accounts for 49% of the time spent in the processing process (Valderrábano, 2011). On the other hand, coffee beans are very difficult to dry to the recommended range of 10-12% for the following reasons:

- The initial moisture to start drying, can vary from 48 to 56%, acquired by the bean in the washing stage; and it is sought to reduce it to the range of 10 to 12% (IICA, 2010).
- If drying is carried out quickly, the parchment hardens. This affects the physical-chemical nature of the parchment (endocarp) and the grain or endosperm.
- When high drying temperatures are used, aromatic components are volatized. Conversely, if low temperatures are used, the physical appearance of the bean is poor and even the taste of the beverage is affected.

The main objective of drying the bean is to avoid its deterioration and preserve its quality during storage, this stage is critical and requires control, as it is decisive for the organoleptic quality of the beverage, due to its direct impact on the sensory quality and directly influences the final price given to the product (Ventura-Cruz et al., 2019).

Coffee drying depends, among other factors, on the prevailing environmental conditions during the process (Prada et al., 2019). In tropical climates, it deteriorates by up to 50%, due to constant rainfall, during the harvest season. This decreases the market value and generates economic losses for the producer (Guevara-Sánchez et al., 2019).

One of the alternatives to improve the coffee drying process is to use solar energy, through the use of solar dryers (Hii et al., 2019), as it allows increasing and stabilising its production and increasing the safety of the final product by protecting it against dust, rain, insects, birds, rodents and domestic animals and thus being able to increase the selling price of the product, due to a higher quality (Tomar et al., 2017; García et al., 2022). Currently, there is a wide variety of designs and sizes of solar dryers that can be used for drying various foods of agricultural origin (Ahmadi et al., 2021). They are low capital and low maintenance cost installations, easy to construct and any material available in the construction area can be used, with designs tending towards simplicity, as there is no significant difference in the results obtained with the more primitive designs compared to the more sophisticated ones (Sharma et al., 2018).

The objective of this study is to compare the costs of setting up and operating a solar dryer for coffee beans, compared to a traditional drying system in African beds and on mats in the Cañada region of the state of Oaxaca. The aim is to reduce contamination by animal fauna and the difficulties of environmental conditions, and with this, increase the sale price of the final product.

Materials and method

The study was carried out in the coffee-growing area of the Cañada region of the state of Oaxaca, in the municipality of Santa Cruz Acatepec belonging to the District of Huautla de Jiménez. The dryer is located in the following geographic location: 18° 9' 44" N and 96° 52' 36" W, at an altitude of 1617 m.

The design of the solar dryer is zenithal (Fig. 1), measuring 7.50 m long and 4 m wide. It has 3 drying levels with 12 screens per level and a total capacity of 36 screens, drying up to 240 kg of wet parchment coffee per cycle, in an average of 8-10 days.

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Figure 1 Design of the zenith type solar dryer for coffee drying

For the economic analysis, a producer with experience in speciality coffees (> 84 SCA protocol points) was chosen, with whom the solar dryer was built, and all the activities and quantities of materials purchased for the implementation of the dryer were recorded, in order to estimate the total investment and calculate the profitability of the construction.

For the evaluation of economic indicators, it was determined:

1. The cost of drying to obtain a kilogram of parchment coffee (Quintanar and Roa, 2017; Singh and Gaur, 2020; Garcia et al., 2022), using the following equations:

$$C_{us} = \frac{C_{an}}{P_{sa}}$$

Where:

C_{an} Total annual cost of the solar dryer.

P_{sa} Total amount of product dried in the solar dryer annually.

Solar dryer annually

To obtain the above, it was necessary to determine the following values:

A. The annual cost of the solar dryer (C_{as}) is given as.

$$C_{as} = C_{ca} + C_{mt} - V_r + C_{oa}$$

Where:

C_{ca} Annual capital cost, including initial infrastructure

initial cost of infrastructure,

C_{mt} Annual maintenance cost of the solar dryer.

C_{oa} Annual operating cost of the dryer.

B. The total amount of products dried annually in the solar dryer (P_{sa}) is given by:

$$P_{sa} = \frac{M_{ps} D_u}{D_n}$$

Where:

M_{ps} Batch-dried product mass in a solar dryer solar dryer,

D_u Number of days during which the dryer is used dryer is used in the year,

D_n Number of days required to dry the material per batch.

Results and discussion

Cost of setting up a solar dryer

At the end of the construction of the solar dryer, all the costs of materials and labour that were used were quantified in order to have an estimated total cost for the implementation of the solar dryer. The initial cost estimate was $11,770.00 pesos, where 65.3% corresponds to the cost of materials, 34.7% to the cost of labour for construction (Table 1). Over the course of a drying cycle, two workdays were employed to handle the wet parchment. However, due to the dew or rain protection infrastructure during the annual drying season, this is considerably reduced as the grain does not have to be stored on a daily basis.

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Material	Quantity	Unit price ($)	Total cost ($)	%
9 x 9 x 259 cm long poles (16 full and 10 halved)	26 pzs	70	1,820	**69.6**
6 cm wide x 2.5 cm thick x 250 cm long sized timber	72 pzs	40	2,880	
7.5 cm wide x 2.5 cm thick x 250 cm long sized timber	52 pzs	45	2,340	
3.7 m wide, 50% shade netting	8 m	85	680	
7.5 m wide greenhouse plastic (720 gauge)	12 m	110	1,320	
5", 3", 2" and ½" nails	3 kg	80	240	
3" hinge	3 pzs	15	45	
Sub-total materials			**9,325**	
Labour (dryer construction)	30 jornales	120	3,600	**30.4**
Labour (sieve construction)	4 jornales	120	480	
Subtotal daily wages			**4,080**	
Total cost of infrastructure			**13,405**	**100**

Table 1 Set-up costs of a solar overhead dryer with three drying levels.Cost of traditional drying

The materials used for this type of drying are two mats and two sacks for daily storage, so the total investment of materials would be $236.00 pesos, which is the only investment, since it does not require labour for the construction of infrastructure. The amount of labour for a drying cycle is one and a half days due to the need to take out and put in the wet parchment coffee daily, as well as having to move it during the hottest hours and store the beans in case of fog or rain.

Cost of setting up on African beds

For drying in African beds, Table 2 lists the materials used to make them, in order to quantify the total cost for their construction, with an approximate total of $2,060.00 pesos, where 82.5% corresponds to the cost of materials and 17.5% to the cost of labour for making the beds. Three working days were estimated to carry out one drying cycle, mainly due to the need to remove and place the wet parchment coffee in the African beds on a daily basis. In addition, having to move it during the hottest hours and storing the beans in case of rain.

Comparing the total costs of materials used and adding the operating costs over a harvest cycle (season), it was found that the unit cost ($/kg) for each type of drying presented considerable differences for transforming washed coffee and transforming it into dry parchment coffee (10 to 12% humidity of the bean).

Material	Quantity	Price/ unit ($)	Total cost ($)	%
Galvanised wire screen mesh (5 squares per inch)	1 roll	1800	1800	**83.2**
2.5 m long poles (8 whole and 4 split in half)	12	70	840	
7.5 cm wide x 2.5 cm thick x 250 cm long dimensioned timber	4	45	180	
Sacks	4	8	32	
1" nail	1.5 kg	90	135	
Sub-total materials			**2,987**	
Day labour for the construction of African beds	5	120	600	**16.8**
Subtotal daily wages			**600**	
Total cost of infrastructure			**3,587**	**100**

Table 2 Establishment costs for implementing drying on African beds

Comparing the total costs of materials used and adding the operating costs over a harvest cycle (season), it was found that the unit cost ($/kg) for each type of drying presented differences for transforming washed coffee and transforming it into dried parchment coffee (10 to 12% humidity of the bean). Thus, the unit costs of drying one kg of washed coffee and transforming it into parchment coffee by using a zenith solar dryer, drying on mats and drying on African beds were $35.91, $31.87 and $44.88, respectively. These are the average costs for the 2023 harvest season (Table 3). Although the cost of solar drying was not the lowest of the three systems compared, the volume of drying was the highest, which translates into a higher harvest volume. The result obtained reflects that the cost of drying in a solar dryer is quite similar to the cost of drying in a traditional way, which represents a difference of $4.04 pesos per kilogram of parchment coffee dried. This indicates that the investment to set up a solar dryer can be justified due to the possibility of improving the selling price of the product.

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Table 3. Estimated economic variables for three types of drying in the cañada region, Oaxaca.

Economic variables	Solar dryer	Backpack	African bed
Ct: cost of infrastructure	$13,405.00	$236.00	$3,587.00
Annual seasonal labour cost*.	$960.00	$720.00	$1,440.00
Can: total annual drying cost	$14,365.00	$956.00	$5,027.00
Psa: Drying capacity per season (kg)	400	30	112
Cus: Cost per kilogram dried	**$35.91**	**$31.87**	**$44.88**
* One season considers on average four drying cycles.			

The results of comparing the drying costs are relatively high, with those reported by Garcia et al. (2022) for a solar drying process carried out in the same region and state.

The initial investment costs (inputs and materials) for the implementation of any drying technology are 69.6% for solar drying and 83.2% for the African bed system and 100% for mats. The drying capacity of parchment coffee for each of the above-mentioned systems is 400 kg, 112 kg and 30 kg, respectively, so this factor limits the drying time, the time of use of the dryer and the number of labourers to follow up the drying process (Poonia et al., 2019; García et al, 2022).

Conclusions

The unit cost for drying one kilogram of parchment coffee in a solar coffee dryer did not register a considerable difference compared to the other drying systems evaluated for the 2023 season, the implementation of a solar dryer can be justified due to the reduction of labour required for the handling of the beans and the higher drying capacity per unit area, in addition to the increase in the quality and safety of the final product.

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Mangrove forests transition between land and ocean, bioremediation areas, refuge and conservation of species

Bosques de manglares, transición entre la tierra y el océano, zonas de biorremediación, refugio y conservación de especies

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Abstract

Mangrove forests provide environmental ecosystem services such as degradation of organic matter, and habitat for terrestrial and bird species. Lack of knowledge causes them to be undervalued and the change of land use due to tourist activities puts their conservation at risk. The objective of this work was to carry out a limnological analysis of phytoplankton biodiversity to contribute to the knowledge and characterization of the protected natural area: La Manzanilla. Applied Methodology: Sampling of environmental variables included: pH, temperature, conductivity, total suspended solids, and dissolved oxygen, determined with a multiparameter probe. The phytoplankton samples were recovered by trawling, with a phytoplankton net, later transferred to the laboratory for analysis. Paper contribution: The populations of *Crocodylus acutus* are permanently monitored by the Ejidal community. Crocodiles are free throughout the estuary. The most abundant species of mangrove was *Rhizophora mangle*. The water column recorded temperature of 25.3 ºC, electrical conductivity of 5.15 mS/cm^2, 2.96 ppm of oxygen dissolved and 2553 ppm of suspended solids. Low light intensity along the water column and the existing abundant organic matter represents a challenge for the survival of algae. Diversity percentages of phytoplankton were cyanobacteria 34.96%, diatoms 30.78%, chlorophytes 16.72%, Charophyta 6.73% and Euglenoids 1.33%.

Biodiversity, cyanobacteria, algae

Resumen

Los bosques de mangle aportan servicios ecosistémicos como degradación de materia orgánica, habitad de especies acuícolas, terrestres y aves. La falta de conocimiento ocasiona que sean poco valorados y el cambio de uso de suelo por actividades turísticas pone en riesgo su conservación. El objetivo de este trabajo fue realizar monitoreo limnológico y analizar biodiversidad de fitoplancton para contribuir al conocimiento y caracterización del área natural protegida La Manzanilla. Metodología: las variables ambientales incluyeron: pH, temperatura, conductividad, sólidos suspendidos totales y Oxígeno disuelto, determinados con sonda multiparamétrica. El fitoplancton se recuperó por arrastre, con red de fitoplancton, las muestras se trasladaron al laboratorio para análisis. Contribución de estudio: Las poblaciones de *Crocodylus acutus* libres en el Estuario, son monitoreadas permanentemente por la comunidad Ejidal. La especie más abundante de mangle fue *Rhizophora mangle*. La columna de agua registró temperatura de 25.3 º C, conductividad eléctrica de 5.15 mS/cm^2, 2.96 ppm de oxígeno disuelto y 2553 ppm de solidos suspendidos. La baja intensidad luminosa en la columna de agua y la abundante materia orgánica, existente, representan un reto para la sobrevivencia de algas. Los porcentajes de Diversidad de fitoplancton fueron: cianobacterias 34.96%, Diatomeas 30.78%, Clorofitas 16.72%, Charophitas 6.73% y Euglenoides 1.33%.

Biodiversidad, Cianobacterias, Algas

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Introduction

Mangroves are coastal forests located in tropical and subtropical areas of the planet, they form the transition between sea and land, are associated with important deltas of rivers that flow into the sea and form shallow lagoons of brackish water. These environments are relevant for the spawning and rearing of commercially and ecologically important fish species (Velazquez-Pérez *et al*., 2020).

According to Torres et al., (2023), the monitoring of biomarkers in aquatic biota is recommended in estuarine regions because the environmental impacts caused by anthropogenic activities such as industry, of all kinds, heavy metals and polycyclic hydrocarbons are highly harmful to molecules, cells, tissues, physiology and behavior of animals in the face of environmental stress.

Mangrove forests on the banks of the world's great rivers provided ancient civilizations with food (through fishing), water, transportation, mythology, art, and religion. Some consider the mangrove to be the prelude to agriculture activities in the Mayan and Mexica civilizations. The environmental contributions of mangroves include the recovery of degraded soils, they are a carbon reservoir (organic matter), and a source of energy and nutrients (detritus) for heterotrophs and retain sediments. They promote soil conservation, as they control tidal erosion and play an important role in the protection and stabilization of the coastline against atmospheric phenomena impacts (hurricanes and cyclones). They function as a filter for pollutants. They provide shade and shelter for terrestrial and aquatic species, migratory or local. In the selected area 40 % to 70% of marine species spawn and is a habitat for 1200 animal species, also it offers protection, food, and a breeding site for oysters and shrimps. It is used for recreational and ecotourism activities. Coastal ecosystems bring benefits to the world's population and mitigate climate change impacts (Calleja & López-Arias, 2022).

The present work was carried out throughout the La Manzanilla estuary, the Ejido has 419 hectares of tropical deciduous and subdeciduous forest, used for the conservation and management of the American crocodile: *Crocodylus acutus.* The site was declared a Ramsar Site of International Importance, as well as an Environmental Management Unit for Wildlife Conservation (UMA) in 2008. see Figure 1.

Figure 1 Environmental management unit Ejido La manzanilla, located in the State of Jalisco, Mexico, a Ramsar Site
Source: Own elaboration

Mangrove forests once covered large tracts of tropical and subtropical coastline, but are disappearing at a rate of 1 to 2 percent per year, with a faster rate in developing countries threatened by tourism and shrimp farms development, expansion of human settlements, industries, agriculture, livestock, and logging (CONABIO-CONANP, 2009).

Within the mangroves of America, 11 species of plants are reported, four belong to the genus *Rhizophora and four to the* genus Avicennia, and *to the genera* Laguncularia, Pelliciera *and* Conocarpus. (Regalado et al., 2016).

In Mexico, mangrove communities represent the highest deforestation rates in the country (7.93%) compared to the national average (1.29%), the Gulf Coast of Mexico is considered one of the areas with the greatest loss of cover (CONABIO). They are used in industry for the production of latex, dyes, wood and pharmaceutical for the production of tannins.

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Methodology to be developed

Researchers from the Polytechnic University of the Guadalajara Metropolitan Area, the Centro Universitario del Sur the Universidad Autónoma de Tlaxcala and students from the Universidad Autónoma de Tlaxcala participated in the monitoring. 10 monitoring stations were established according to the geographic coordinates shown in Table 1. Station No. 1 was located at the farthest position and Station 10 was located at the closest position from the jetty, respectively.

Experimental design

No. of station	N	W
1	19º 18´23.8´´	104º 47´17,2´´
2	19º18´19.5´´	104º47´18.7´´
3	19º18´12,3´´	104º47´21,9´´
4	19º18´09,9´´	104º47´22.4´´
5	19º18´07,8´´	104º47´17.5´´
6	19º18´05,5´´	104º47´24.7´´
7	19º18´05,6´´	104º47´29.7´´
8	19º17´55,5´´	104º47´26.2´´
9	19º17´17,9´´	104º47´19.1´´
10	19º17´10.9´´	104º47´18.7´´

Table 1 Location of monitoring stations
Source: Own elaboration

Limnological monitoring. A multiparameter probe was used for the analysis of environmental variables *in situ*, pH, conductivity, dissolved oxygen, total suspended solids and temperature were determined. Secchi disc was used to determine the transparency of the body of water.

Biodiversity analysis. It was carried out by horizontal trawling with a phytoplankton net with a diameter of 30 cm, 50 cm in length and 40 µm in pore diameter, for 60 seconds. The samples were fixed with formaldehyde and transferred to the microbiology laboratory of Universidad Politécnica de la Zona Metropolitana de Guadalajara. The analysis was performed with the help of a Leica microscope, with a 10x and 40x objective lens. Databases and specialized literature were used for the classification.

Multiple alignment and construction of phylogenetic trees. A search was conducted using the database of the National Center of Biotechnology Information (NCBI), from which the sequences of *Spirulina* major strain PCC6313 16S ribosomal, RNA partial sequence were selected. For the elaboration of the phylogenetic trees, manual selection was carried out and they were elaborated with the algorithm of maximum likelihood.

Figure 2 Limnological monitoring carried out at UMA La Manzanilla, Jalisco, Mexico
Source: Own elaboration

Results

Regarding the mangrove forest, the dominant species was *Rhizophora mangle L*. (red mangrove), followed by *Laguncularia racemosa* L. (white mangrove). They provide mangrove habitat services and functions, wastewater filtration, carbon sequestration, nitrogen fixation, and ecosystem self-preservation. Mangroves are Federal property, and the Official Mexican Standard 022 aims to protect coastal wetlands, see Figure 3.

Figure 3 Mangrove tree, characteristic of the Manzanilla estuary, México, 2023
Source: Own elaboration

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The red mangrove is an evergreen tree, distributed along the coasts of the Gulf, the Pacific and the Caribbean, it grows in environments with great water movement and variable salinity, its soils have a high content of organic matter. Its height is estimated to be 30 m tall with a straight trunk, with simple or dichotomously branched adventitious roots and numerous lenticels (taproots or stilts) that are anchored in waterlogged and fiery soils. (CONABIO).

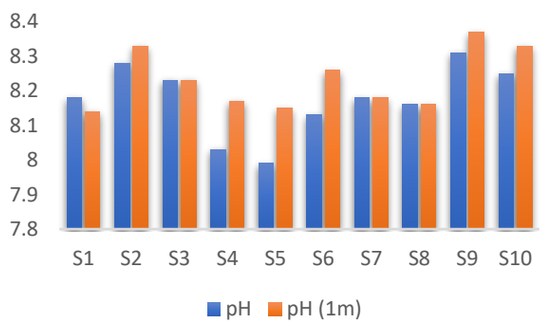
Laguncularia racemosa L. (white mangrove), known as a mangrove tree of the tropical coasts of America and West Africa, its wood is not durable, having a high density and a tendency to deform, therefore, it is used as fuel and its bark and leaves are a source of tannins, astringents and tonics. It is the tree species most tolerant to low temperatures, compared to other mangroves, it excretes salt and tolerates high salinity levels from 0 to 90 ppm, being intolerant to shade. It is usually associated with other species, it is not usually the dominant species, although it is characterized by a shallow, large, extended and horizontal root system (peg), which makes it susceptible to collapse by wind (Jimenez, (n.d.).

In a study carried out in Bahía Portete in Guajira, Colombia, the coast is bordered by dense populations of red mangrove and black mangrove, it is worth mentioning that these species are considered to be in a state of threat. (Gómez-González, 2017).

Crocodylus acutus is the crocodilian species with the largest distribution in the world, in México its distribution ranges from Sinaloa to Chiapas, the Caribbean Sea, Quintana Roo and Yucatán. In 1970 its population decreased considerably due to illegal hunting and the modification of its habitat, for which a national ban was declared and included in the list of the Endangered Species Act (ESA). It is expected that these actions would favor the increase of crocodilian populations (Lopez-Luna et al, 2013).

Figure 4 *Crocodylus acutus*, the photograph was taken in the La Manzanilla estuary, a protected natural area of international importance
Source: Own elaboration

Regarding the environmental variables, pH (determined at a depth of 30 cm) was recorded in the range of 7.99 to 8.31 with an average value of 8.2. The deeper the depth (1m), the higher the alkalinity, with values ranging from 8.14 to 8.37 (see Graph 1). Our results are similar to those obtained at Station 1 of San Juan Bay, reported on September 29, 2022, with values of 8.02 and 7.86.



Graphic 1 pH values obtained in the crocodile tree Manzanilla
Source: Own elaboration

The average dissolved oxygen level was 2.96 ppm with a range of 2.74 to 3.10. In the estuary of the Churute Mangroves, values in the range of 2 and 6.5 mg were recorded. $^{L-1}$ with hypoxia values (less than 2 mg. L-1) in the months of January to April (Marín et al., 2022).

The average value of total suspended solids was: 2553.1 ppm with a range of 2104 to 2771 ppm. The values drop as you move away from the jetty (station one). (See Figure 2).

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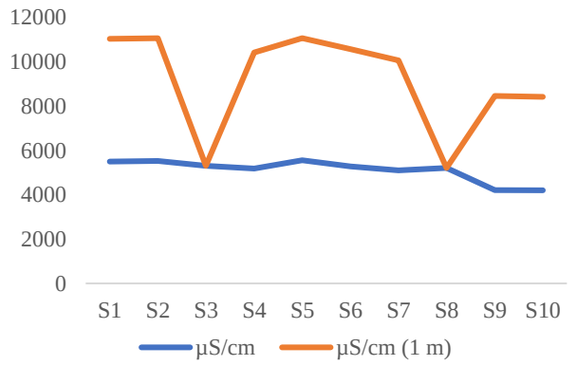
Industrial and domestic effluents carry pollutants that are transported through rivers or leachate into estuarine sediments. Pollutant molecules are usually associated with suspended particulate matter, where they become bioavailable to aquatic invertebrates, causing bioaccumulation when their detoxification levels are exceeded. For this reason, the study of metallic contaminants in sediments and biological matrices is recommended (Santos et al., 2021).

Graphic 2 Total dissolved solids content in the mangrove swamp La Manzanilla, Jalisco, Mexico, spring 2023.
Source: Own elaboration

The average temperature was 25.34 ºC with a range of 23.21 to 27.50 ºC. Our results are similar to those reported for the Churute Mangrove Estuary, which recorded temperatures in the range of 24.2 to 29.2 ºC, and in the Estero Salado, with a range of 26.1 ºC to 36.0 ºC during 2016, both areas located in the Guayas estuary in Ecuador, characterized as the largest estuary in western South America (Marin et al., 2022). The average temperature reported in Bahía Portete, La Guajira, Colombia is 29.8 ºC (October) and 25.4 ºC (January), (Gómez-Gonzalez, 2017).

Regarding visibility, the highest transparency was obtained at station 9 with a value of 68 cm and the lowest value was obtained at station 1 (boarding) with a value of 35 cm. The mean electrical conductivity was 5.1536 mS/cm^2, ranging from 4.984 to 5.788 mS/cm^2. In a study carried out on the Anil Are River in São Luis, capital of the state of Maranhao, Brazil, the transparency of the water was in the range of 0.19 to 1.41 m during the rainy period and 1.60 in the dry period, it is worth mentioning that the surface conductivity range was recorder from 7.64 to 49.29 mScm^{-1} during the rainy period and 31.8 to 55.40 mScm^{-1} in the dry period (Machado et al., 2022).

Low visibility is associated with the re-suspension of sediments by the action of the tides and organic debris derived from the degradation of mangrove leaves, known as detritus, and conductivity is influenced by the flow of seawater.



Graphic 3 Turbidity, determined with a Seshi dish in the mangrove swamp of Manzanilla, Jalisco, Mexico during the spring season
Source: Own elaboration

The ecosystem services provided by mangroves include protection from erosion of the coastline, and physical barriers against hurricanes, tropical storms, tidal waves, or tsunamis (prevents flooding), also they are a source of forest resources, flora and fauna, and promote tourism. Magroves provide a refuge and feeding area for vertebrates and invertebrates, and are a source of biomass for food chains (Garcés et al., 2021).

Regarding biodiversity, cyanobacteria were the most abundant species (34.96%), followed by diatoms (30.78%), chlorophytes (16.72%), charophytas (6.73%) and Euglenoides (1.33%). The dominant species was *Microcystis aureginosa (cyanobacteria)*, followed by Aphanothece (*cyanobacteria*), Prorocentrum micans Ehrenberg *(Dinoflagellate), Gyrosima acuminatum (diatomea) and* Chlorella *(*Chlorophyte). See Graphic 4.

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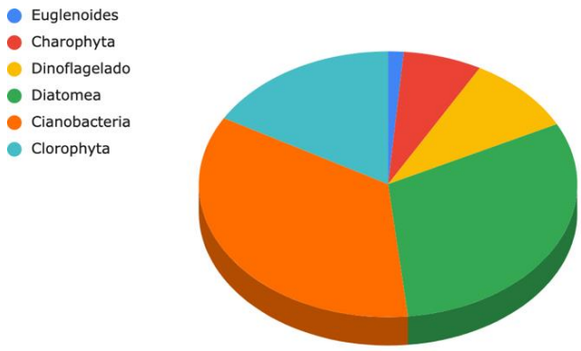

Graphic 4 Phytoplankton biodiversity identified from limnological monitoring carried out in the Manzanilla Estuary
Source: Own elaboration

In coastal environments, there are is an intense interactions of marine, river and terrestrial factors that favor primary production. They provide habitat and a great diversity of species (Delgado et al., 2022).

17 cyanophytes species were identified: *Planktolyngbia limnetica, Pseudanabaena, Pseudanabaena limnética, Pseudanabaena constricta, Microcystis, Microcystis Aureginosa, Synechococcus aeruginosos, Aphanizomenon flos aquaea, Planktothrix agardhii, Limnothrix redekei, Aphanocapsa grerillei, Spirulina getieri, Leptolyngbya lagerheinii, Rhabdogloea yucatanensis, Anabaena, Aphanothece, Oscillatoria.*

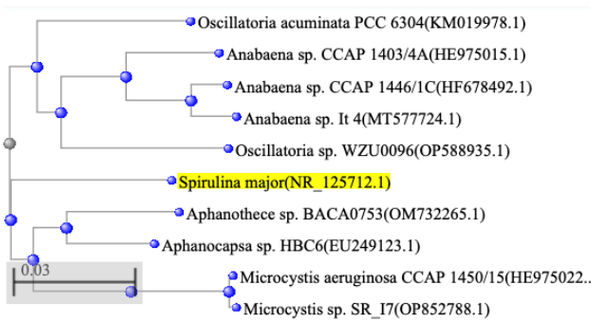

Figure 5 Cyanobacteria phylogenetic tree obtained from the Genbank database, accessed January 25, 2023
Source: Own elaboration

Furthermore, 15 diatomaceus species were identified: *Coconeis placentula Ehrenberg, Fragilaria Crotonensis, Nitzschia lancelota, Gomphonema gracile, Aulacoseira granulata var. augustissima, Gyrosima acuminatum, Navicula viridula Coscinodiscus, Entomoneis alata, Navicula Radiosa, Navicula bacilum, Cymbella minuta, Fragilaria capuchina, Pinularia ocurans, Gomphonema augustatum.*

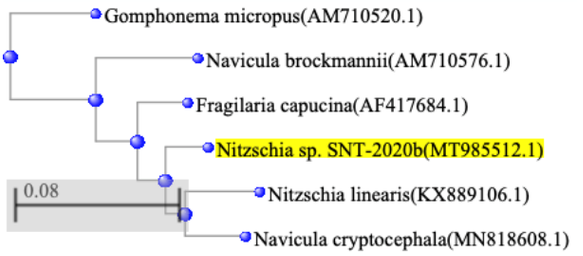

Figure 6 Phylogenetic tree of diatoms identified in the body of water
Source: Own elaboration

8 species of chlorophytes were identified: *Pediastrum simplex, Monoraphidium, Chlorella, Closterium parvulum, Chlorella, Botryococcus, Coelastrum microporum, Staurastrum gracile*

3 Charophyta species *were identified: Closterium kuetzingii, Closterium sp. Staurastrum gracile.* Regarding the dinoflagellates, the following were identified: *Prorocentrum micans Ehrenberg*. The Euglenoids corresponded to *Phacus acuminatus, Euglena* y *Euglena acus*.

Studies of prokaryotic biodiversity in tropical and subtropical estuarine ecosystems reveal a high biodiversity of archaea belonging mainly to anaerobic methanogens and methanotrophs, ammonium-oxidizing archaea and members of the *Superphyllum Asgard*. These organisms participate in the Carbon, Nitrogen and Sulphur cycle, under aerobic and anaerobic conditions with heterotrophic or autotrophic metabolisms in accordance with the existing ecosystem and are among the most productive on the planet (Torres-Alvarado y col., 2023).

Gratitude

We would like to thank the Ejidal Community of the Manzanilla Estuary for the facilities granted for the realization of this work.

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Conclusions

Throughout the estuary, the concentration of salts from saline intrusion causes an average electrical conductivity of 5.15 ms/cm2 (selective for some species), warm temperatures of 25.34 ºC favor microbial metabolism.

The estuary receives daily discharges of pollutants of a chemical and biological nature. The transparency range was from 68 to 35 cm, the suspended matter with an average value of 2553 ppm stains the water with a brown hue, the sedimentation of particles favors the presence of anaerobic microenvironments. Bacteria using biogeochemical cycles predominate in these ecosystems and produce soluble forms of nitrates, phosphates, and sulfates.

The most abundant algae species in the estuary: are: cyanobacteria (*Microcystis aeruginosa* and *Aphanothece*), dinoflagellates and diatoms use these ions as nutrients and through photosynthesis maintain oxygen levels of 2.96 ppm with a range of 2.74 to 3.10 ppm necessary for the life of aerobic species.

The roots of mangrove trees promote the generation of microenvironments, the presence of zooplankton filter feeders, and macroinvertebrates make this ecosystem the ideal place to detoxify organic matter. It is worth mentioning that the habitat of species of great importance and transcendence are *Crocodylus acutus*, *Rhizophora mangle* and *Laguncularia racemosa*.

The contribution of mangrove forests is undoubtedly very important for the treatment of water prior to its discharge into the river, its loss due to land use change associated with tourism activities or urban city developments, causes an irreversible negative impact. Mangroves are the most efficient natural treatment systems on the planet, not to mention all the additional contributions they provide as ecosystem services.

Clearly explain the results obtained and the possibilities for improvement.

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Study of spin coating variables for deposition of hole transport nanolayer used in hybrid perovskite solar cells

Estudio de variables de spin recubrimiento para deposición de nano capa transportadora de agujeros utilizada en celdas solares híbridas de perovskita

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Abstract

PEDOT:PSS (poly(3,4-ethylenedioxythiophene):poly (styrene sulfonate)) is a conductive polymer, which has among its properties a high transmittance to visible light, and has a relatively high electrical conductivity for an organic polymer. This polymer is widely used as one of the key materials in the structure of a perovskite organometallic solar cell (POSC). The main function of PEDOT:PSS is to act as a carrier layer for the positive charges or holes generated by sunlight and direct them to the output electrode of the device. This layer has a thickness of approximately 10 to 50 nanometers. In this research, the spin coating technique is exposed to deposit PEDOT:PSS films with different thicknesses. To achieve this purpose, three variables must be taken into account: the rotation speed, which varies between 1000 and 6000 revolutions per minute. The amount of solution that ranges from 40 to 100 microliters of solution, and the method of deposit on the substrate, which can be with the spin coater off or on when the solution is poured. It was found that depositing the PEDOT:PSS solution with the spin coater turned on at 5000 RPM and 100 microliters of solution yielded nano films that exhibit greater homogeneity and adherence. Leading to the conclusion that this is the best combination for producing uniform and homogeneous hole-transporting films, which should translate into an improved solar cell efficiency.

PEDOT:PSS, spin coating technique, perovskite solar cell

Resumen

PEDOT:PSS (poli(3,4-etilendioxitiofeno):poli(sulfonato de estireno)) es un polímero conductor, que tiene entre sus propiedades una alta transmitancia a la luz visible, y tiene una conductividad eléctrica relativamente alta para un polímero orgánico. Este polímero se utiliza ampliamente como uno de los materiales clave en la estructura de una celda solar organometálica de perovskita (CSOP). La función principal de PEDOT:PSS es actuar como capa portadora de las cargas positivas o agujeros generados por la luz solar y dirigirlas al electrodo de salida del dispositivo. Esta capa tiene un espesor de aproximadamente 10 a 50 nanómetros. En esta investigación, se expone la técnica de spincoating para depositar películas de PEDOT:PSS con diferentes espesores. Para lograr este propósito se deben tener en cuenta tres variables: la velocidad de rotación, que varía entre 1000 y 6000 revoluciones por minuto. La cantidad de solución que oscila entre 40 y 100 microlitros de solución, y el método de depósito sobre el sustrato, que puede ser con el equipo spin coating apagado o encendido cuando se vierte la solución. Se descubrió que depositar la solución PEDOT:PSS con el spin coating encendido a 5000 RPM y 100 microlitros de solución produjo nanopelículas que exhiben mayor homogeneidad y adherencia. Lo que lleva a la conclusión de que esta es la mejor combinación para producir películas transportadoras de agujeros uniformes y homogéneas, lo que debería traducirse en una mejora de la eficiencia de las células solares.

PEDOT:PSS, Spin coating, Celdas solares perovskite

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† Researcher contributed as first author.

Introduction

PEDOT:PSS(poly(3,4ethylenedioxythiophene): poly(styrene sulfonate)) is a polymer widely used in electronic and photovoltaic applications. One of its most prominent uses is as a key material in the structure of perovskite-based organometallic solar cells (PSCs). PSCs exhibit promising efficiency due to the combination of perovskite-structured materials as a light-absorbing layer and PEDOT:PSS as a hole-transporting layer [1]. PEDOT:PSS offers high visible light transmittance and a relatively high electrical conductivity for an organic polymer, having reached 6259 S cm−1 for thin films and 8797 S cm−1 for single crystals [2], making it an attractive option for improving the efficiency and stability of solar cells.

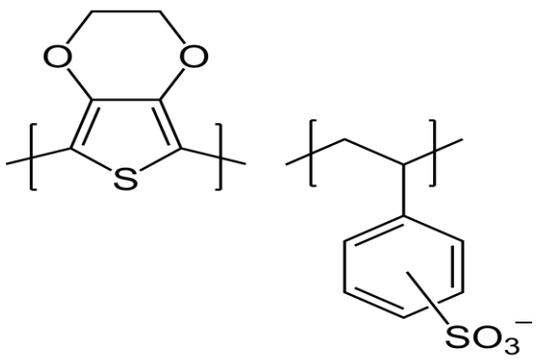

Figure 1 PEDOT:PSS molecule

Methodology

Spin coating technique was explored to deposit PEDOT:PSS thin films with different thicknesses. Spin coating is a method widely used in the electronic device industry to produce uniform and controlled films [3]. Experiments were carried out by modifying three main variables: the rotation speed, the amount of solution and the deposition method on the substrate. For this, a spin coater brand/ model VTC-50 A was used.

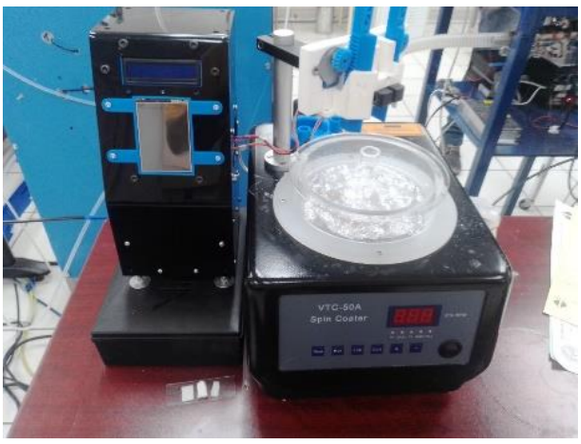

Figure 2 Spin Coater VTC-50 A

First, the rotation speed of the spin coater was varied in the range of 1000 to 6000 revolutions per minute (RPM). Different rotation speeds were selected to investigate their influence on the thickness and uniformity of the deposited films. A higher rotation speed was expected to provide thinner and more uniform films due to greater dispersion of the solution over the substrate surface.

Secondly, the amount of PEDOT:PSS solution used during the spin coating process was evaluated . Different volumes of solution were tested, varying from 40 to 100 microliters. The objective was to determine the optimal amount of solution necessary to obtain uniform and adherent films, avoiding excess solution that could generate defects or lack of adhesion.

Figure 3 40/100 µl of PEDOT:PSS were deposited varying the speed from 1000 to 6000 RPM

Third, the deposition method on the substrate was investigated. Two different approaches were compared: the spin coater turned off during solution deposition and the spin coater turned on when pouring the solution onto the substrate. It was analyzed whether the activation of the spin coater during deposition had any effect on the uniformity and adhesion of the films.

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Figure 4 Deposition with the spin coating: a) OFF and b) ON.

The depositions were carried out on 22 by 22 mm D 263® borosilicate glass substrates with a thickness of 0.13 to 0.17 mm, which have a high transmittance of 92% [4].

Results and discussion

After performing 18 experiments and measurements, promising results were obtained regarding the quality of the deposited PEDOT:PSS films. It was observed that the combination of a rotation speed of 5000 RPM, 100 microliters of solution and the spin coater turned on during deposition produced films with greater homogeneity and adhesion.

The films deposited with this configuration presented an adequate thickness and a uniform distribution on the substrate. Furthermore, good adhesion was observed between the PEDOT:PSS film and the substrate, which is essential to ensure efficient charge transfer through the device.

UV-Vis characterization studies were carried out in the range of 200 to 800 nm in the electromagnetic spectrum. Transmittance results are shown in Figure 4, because perovskite (CH3NH3PbI3) has an approximate absorption range of 400 to 800 nm and its maxima are approximately between 400 nm and 560 nm. To highlight the absorption range of the perovskite in the transmittance response of the samples, a script was made in MicroPhyton.

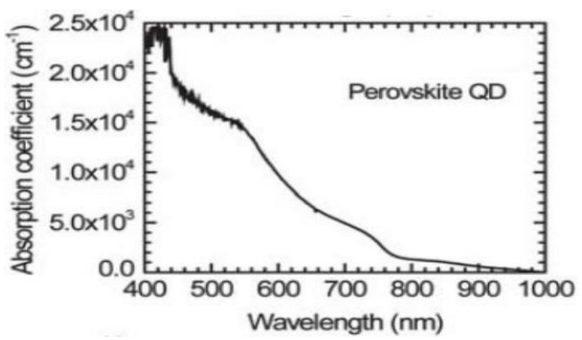

Figure 6 Absorption coefficient of CH3NH3PbI3 Perovskite
Source: [8]

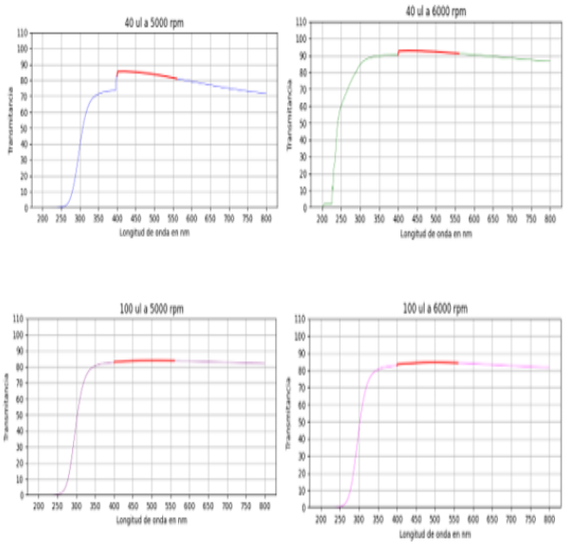

Figure 7 Transmittance graphs

Using the Scanning Electron Microscopy (SEM) technique, you can observe the formation of the layer and determine its thickness in the samples, as shown in Figure 5.

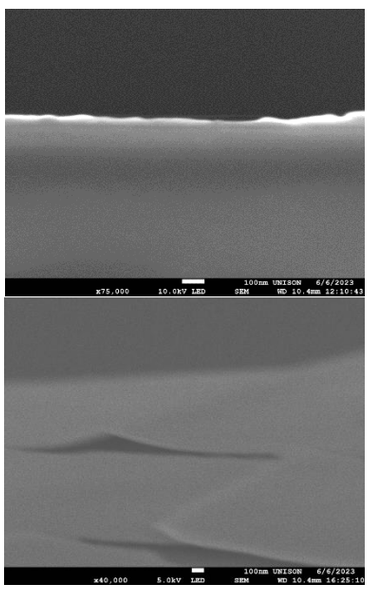

Figure 8 SEM characterization

Multiple thickness measurements were carried out during PEDOT:PSS deposition using ImageJ. It was observed that nanolayers were obtained an average of 27 nm.

The most successful combinations were obtained with volumes of 40 microliters at 6000/5000 RPM and 100 microliters at 6000/5000 RPM, both using the spin coater in operation. For volumes of 40 microliters, high transmittances were observed, while for those of 100 microliters, the curves showed a more uniform behavior. In addition, better coverage in the area was seen when 5000 RPM was used.

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With which the formation of thin nanolayers with an average thickness of approximately 27 nm was obtained.

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Conclusions

In summary, the results obtained in this research demonstrate that the spin coating technique is effective for depositing PEDOT:PSS nanofilms with desired properties in terms of thickness, uniformity and adhesion. Additionally, the optimal combination of process parameters was identified, including a rotation speed of 5000 RPM, 100 microliters of solution, and the use of the spin coater on during deposition.

The use of this combination allowed to obtain PEDOT:PSS nanofilms with greater homogeneity and adhesion, which translates into a potential improvement in the efficiency of solar cells. These findings contribute to the advancement in the development of PEDOT:PSS-based photovoltaic technologies and offer opportunities to further improve the efficiency and stability of perovskite organometallic solar cells.

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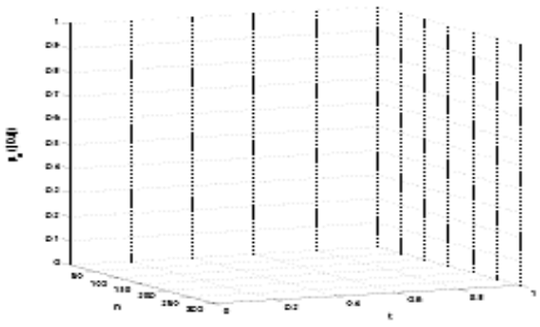

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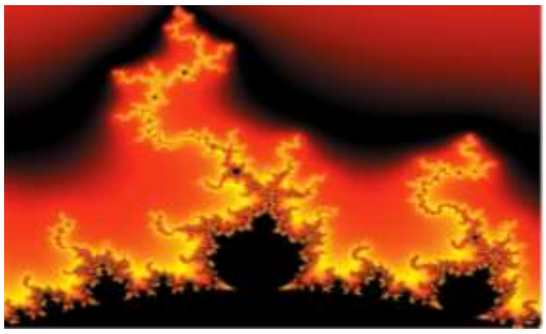

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