

CHARACTERIZATION OF PLASTIC PARTICLES IN COASTAL SEDIMENTS OF PLAYA SAN LUIS, CUMANÁ, VENEZUELA

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Received: 15-07-2024

Accepted: 12-09-2024

Published: 27-03-2025

ABSTRACT

Due to their versatility and affordability, plastics have become widely used in packaging and various other sectors, significantly increasing plastic waste generation. Environmental concerns arise as plastics degrade into microplastics; particles smaller than 5 mm when exposed to the environment. Despite increased research on plastic pollution, there are many information gaps worldwide, particularly in Venezuela. Additionally, there is a lack of chemical characterization of these pollutants. This study aims to reduce the information gap by characterizing plastic particles collected on an urban beach in Sucre state, Venezuela. In February 2021, thirty sediment samples of two sectors were collected from San Luis Beach in Cumaná for examining the plastic particle content. Density separation using a 5 mol/L NaCl solution was employed to extract particles, which were subsequently categorized by size, shape, and color. Furthermore, FTIR analysis and photographs with a digital optical microscope of selected particles were conducted. A total of 485 items in Sector A and 251 items in Sector B were recovered from the sediments, with fragments being the predominant shape and blue and green as the dominant colors. These analyses allowed for the identification of poly(ethylene-co-vinyl acetate) and polyester, as well as the presence of moisture, adsorption of other contaminants, and the presence of pigments on the particles.

Keywords: Plastics; microplastics; pollution; environmental impact.

CARACTERIZACIÓN DE PARTÍCULAS DE PLÁSTICO EN LOS SEDIMENTOS COSTEROS DE LA PLAYA SAN LUIS, CUMANÁ, VENEZUELA

RESUMEN

Por su versatilidad y asequibilidad, los plásticos se han utilizado ampliamente en el envasado y en otros sectores, aumentando significativamente la generación de residuos plásticos. Existen preocupaciones ambientales porque se degradan en microplásticos; partículas menores que 5 mm cuando están expuestas al ambiente. Pese al aumento de la investigación sobre la contaminación plástica, existen vacíos de información en todo el mundo, particularmente en Venezuela, aunado a la falta de caracterización química de estos contaminantes. Este estudio tiene como objetivo reducir la brecha de información al caracterizar partículas plásticas muestradas en una playa urbana del estado Sucre, Venezuela. En febrero de 2021, se recolectaron treinta muestras de sedimentos de dos sectores de la Playa San Luis en Cumaná para examinar el contenido de plásticos. Se utilizó la separación por densidad con NaCl 5 mol/L para extraer partículas, que posteriormente se categorizaron por tamaño, forma y color. Se realizaron análisis espectroscópico FTIR y fotografías con un microscopio óptico digital de partículas seleccionadas. En total se recuperaron desde los sedimentos, 485 ítems en el sector A y 251 ítems en el sector B, siendo los fragmentos la forma predominante y, azul y verde los colores dominantes. Los análisis permitieron identificar la presencia de poli(etilen-co-vinil acetato) y poliéster, así como la presencia de humedad y pigmentos y la adsorción de otros contaminantes en las partículas.

Palabras claves: plásticos; microplásticos; contaminación; impacto ambiental.

INTRODUCTION

Marine anthropogenic litter (MAL) refers to any durable, processed solid material resulting from human activities disposed of in the oceans, whether discarded intentionally or accidentally. Plastic stands out as the most abundant and persistent component of MAL worldwide [1,2]. Documentation of marine plastic pollution dates back to the 1970s, highlighting the long-known presence of this issue [3,4]. Currently, plastic represents a global-scale problem, manifesting in floating debris scattered across water surfaces, accumulating along coastlines under the influence of waves and tides, and persisting on both the ocean surface and deep-sea floors [5], emphasizing that the marine environment serves as the ultimate destination for a significant volume of plastic waste originating from both terrestrial and marine origins [6]. Projections suggest that, under current trends, this input into the ocean could escalate to 53 million tons by the year 2030 [7], implying that marine environments are facing significant challenges attributed to the presence of plastic litter, predominantly consisting of macroplastics, such as plastic bags, bottles, and containers, sweet packets, lollipop sticks, and debris associated with fishing and other activities mainly due to inadequate waste management [8,9,10].

Macroplastics can exacerbate the negative impacts on marine flora and fauna by degrading into microplastics, smaller particles (<5mm) that form through mechanical and chemical breakdown processes under environmental conditions [11,12]. Furthermore, plastic debris can break down into even smaller particles, commonly referred to as nanoplastics, typically characterized by a size of less than 1 μ m [13,14]. When the microplastics sink to the seabed, they can accumulate in benthic habitats and be ingested by various organisms, including commercial fishing species [15]. These impacts extend to both the marine and human food chains, as microplastics have been detected in seafood intended for human consumption [16,17].

In Latin America and the Caribbean region, as emphasized by Martinelli Filho and Pereira Monteiro (2019) [18] and Ita-Nagay (2022) [19], the bulk of microplastic research is conducted in a handful of countries, notably Brazil, Colombia, Mexico, Argentina, Peru, and Uruguay. This underscores the necessity for a broader and more geographically diverse investigation into microplastic pollution across the region. Particularly in Venezuela, studies on this area of knowledge are scarce. Therefore, a comprehensive understanding of the origin and distribution of these plastic pollutants in the marine environment is crucial for addressing and ultimately resolving this issue both at the local and regional levels. The objective of this study is to assess the plastic particles found in the surface sediments of an urban beach located in Cumaná, Sucre state, which is used for tourism purposes, aiming to contribute valuable insights into plastic pollution in Venezuela.

MATERIALS AND METHODS

Study Area

Cumaná is situated in the northeastern region of Venezuela (lat. 10.45397/long. -64.18256) and is characterized by its fishing and port activities around the main mouth of the Manzanares River, where urban and industrial activities also exist [20], acting as pressures on this coastal ecosystem that may contribute to plastic accumulation along the coast. Specifically, San Luis Beach is located at the western of the city, with a sandy bottom and spanning over 5 km in length. Along its stretch are residences, hotels/inns, and informal food sellers, making it a residential-tourist area, as various sports, recreational, and tourist activities take place, along with formal and informal economic activities.

Sampling design

To analyze the presence of plastic particles associated with the surface sediments of this beach, two sectors

were considered: Sector A, located close to the College of Physicians, and Sector B, corresponding to the adjacencies of the Hotel Los Bordones (Figure 1), in addition rental services (kiosk, tables, and chairs), as well as food and beverage sales were present. In each sector, three 100-meter transects were considered, following the guidelines of Besley et al. (2017) [21] with some modifications. The first transect (T1) was in the subtidal zone, and the other two transects were in the intertidal zone; the second transect (T2) was specifically located on the trace of the last tide, and the third transect (T3) was 5 meters towards the mainland. Five equidistant points (25 m apart) were fixed on each transect. A 0.25 square meter quadrat, 1.5 cm deep, was placed at each sampling point, and approximately 1-2 kg of surface sediments were extracted using a metallic spoon and transferred to labeled glass bottles. Sample collection took place during the dry season in February 2021. In total, 30 samples were collected.



Fig. 1. Location of San Luis Beach in Cumaná, state of Sucre, Venezuela, location of the sectors, and photos that illustrate the sampling process.

Extraction of plastic particles from sediments

The samples were dried at room temperature and sieved using a sieve cascade consisting of mesh sizes of 4.76 mm, 1.0 mm, and 0.5 mm to facilitate the separation of plastics from the sediment matrix. All obtained

granulometric fractions were observed with a 10x magnifier to recover visible plastics. Subsequently, a density separation method was employed to enhance separation, utilizing a cost-effective and minimally toxic reagent reported in the literature, 5 mol/L NaCl [22]. The mixture was stirred with a glass rod, and the supernatant was filtered. Each filter paper was air-dried at room temperature for further visual examination with the naked eye and a 15x magnifier. This procedure was repeated three times for each sample. After the density separation procedure, the plastics obtained were added to those recovered from the initial observation. Finally, the total content of plastic items and the abundance (items/m²) in each sector are reported. Preventive measures were implemented to safeguard the samples from contamination, following some of the recommendations proposed by Prata et al. [22].

Analysis and classification of plastics

Plastic particles were categorized based on their shape, which included fibers, fragments, granules, microspheres, sponges, and foam. Moreover, they were classified according to color, encompassing white, yellow, gray, transparent, blue, black, red, green, multicolored, and other hues [23]. Additionally, they were classified according to size into mesoplastics (>4.76 mm) and microplastics (<4.76 mm) based on the sieves available for this study. Additionally, three particles were selected for Fourier Transform Infrared Spectroscopy with Attenuated Total Reflectance (FTIR-ATR) analysis using a Perkin Elmer Frontier device. Micrographs of these particles were also captured with a digital optical microscope (AIGO EV 5610 with 4X magnification).

RESULTS AND DISCUSSION

Plastic particles were found in all sediment samples from the two sectors considered on the San Luis Beach in Cumaná, Sucre state, Venezuela. Plastic pollution in sandy beach sediments has been reported by several

authors (e.g., Bosker et al. 2018 [24], Garcés-Ordóñez et al. 2020 [25]). A total of 501 particles of different shapes were recovered in Sector A, and 238 in Sector B (Table 1), with fragments being the most prevalent shape in both beach sectors (217 items in Sector A and 115 in Sector B), which suggests the breakdown of larger rigid plastic litter deposited on the shore or in the seawater, resulting from mechanical, chemical, and biological decomposition [26,27]. These plastic particles could have originated locally through the degradation of plastic litter generated on the beach by tourist activities and deficient management. Alternatively, they might have been transported from other areas by marine currents, waves, tides, and wind [28]. The second recovered shape, fibers are mainly associated with fishing activities involving nets and ropes that may break during fishing or are intentionally or accidentally discarded in the marine environment, highlighting the potential presence of ghost nets [26,29]. On the other hand, synthetic textiles shed microfibers during washing that can be introduced into water bodies through wastewater [30].

Table 1. Total plastic particles retrieved from the two sectors of San Luis Beach, categorized by their respective shapes.

SHAPE	SECTOR A	SECTOR B	Total items
Fibers	103	81	184
Fragments	217	115	332
Microspheres	0	2	2
Films	92	9	101
Foam	89	31	120
Total items	501	238	739

The films recovered mainly in Sector A (College of Physicians) can be related to the degradation of plastic bags used in food packaging and consumption on the beach [31,32], and sponges (43 items in Sector A and 15 in Sector B) have been reported on other beaches, possibly associated with buoys or insulating materials used in fishing activities [33]. The foam recovered mostly consisted of polystyrene, either in spheres or as

sheets from trays or white containers used in food sales, which were easily identified by the naked eye. Foam serves various purposes, such as packaging, building materials, and in fishing activities [34, 35]. However, foam items of colors other than polystyrene were also recovered. Finally, the microspheres were scarce on this beach, since only 2 items were found in Sector B. Regarding the colors of the plastic particles, Fig. 2 shows that the main colors identified in this study were blue and green corresponding to fragments and fibers.

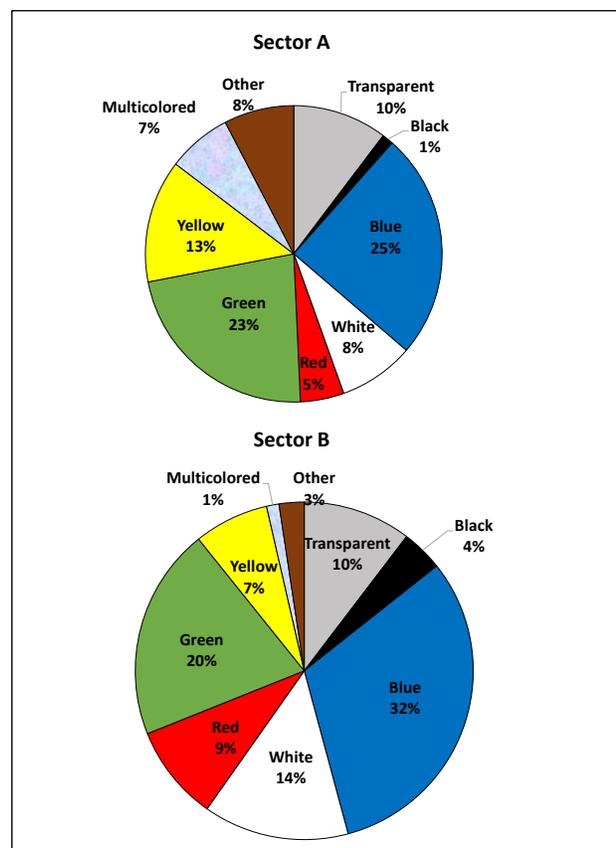


Fig. 2. Color distribution of plastic particles recovered from surface sediments of San Luis beach, Sucre state, Venezuela.

Fig. 3 displays the abundance of plastic particles as a function of size for both sectors, showcasing a higher accumulation in Sector A (133.6 items/m²) compared to Sector B (63.47 items/m²). Microplastics, particles smaller than 4.76 mm, were the most abundant in the analyzed sectors of San Luis Beach, specifically 91.5 items/m² for Sector A and 57.6 items/m² for Sector B.

These values are higher than those reported for Cispata Beach and Tumaco Bay in Colombia, and lower than those found in Santa Marta and Cartagena. Moreover, they are lower than the findings in Puntarenas (Costa Rica), the Caribbean coast of Panama, Costa Rica, and two Colombian beaches (Table 2).

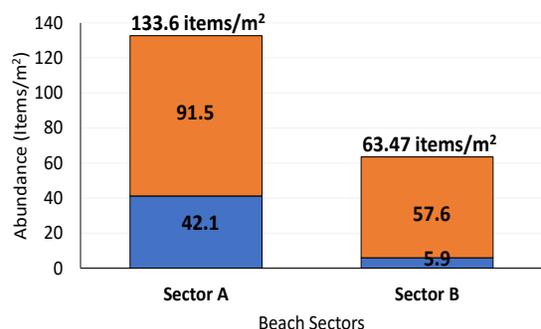


Fig. 3. Abundance of plastic particles recovered from beach sediments as a function of size.

The presence of varying sizes of plastics on sandy beaches has been associated with their tourist utilization [25,39]. Playa San Luis is a highly frequented urban beach used for tourism and recreational activities.

Table 2. Abundance of microplastics on some Latin American beaches.

Beaches/ locality	Microplastics abundance (ítems/m ²)	Reference
Blanca Beach, Cispata, Colombia	36	Garcés-Ordóñez <i>et al.</i> (2022) [36]
Tumaco Bay (Pacific)	6.5	Garcés-Ordóñez <i>et al.</i> (2020) [31]
Cartagena, Colombia	818	Garcés-Ordóñez <i>et al.</i> (2020) [31]
Santa Marta, Colombia	467.5	Garcés-Ordóñez <i>et al.</i> (2020) [25]
Costa Caribe (Panamá)	353	Delvalle de Borrero <i>et al.</i> , 2020) [37]
Puntarenas (Costa Rica)	1400	Sagot Valverde (2022) [38]

However, in Sector B, there are kiosks/restaurants selling food, snacks, and beverages, and renting tents, chairs,

and tables, which may influence the content of plastic litter and microplastics because they are responsible for frequently cleaning this beach sector.

Three of the most abundant particles (by type and color) were selected, to ascertain the polymeric composition using FTIR-ATR:

- (a) A white fiber found in Sector A (Point 4, Transect 2).
- (b) A black rubber fragment found in Sector A (Point 4, Transect 2).
- (c) A blue foam retrieved in Sector B (Point 5, Transect 3).

Figures 4-6 show micrographs of some of the microplastics found.

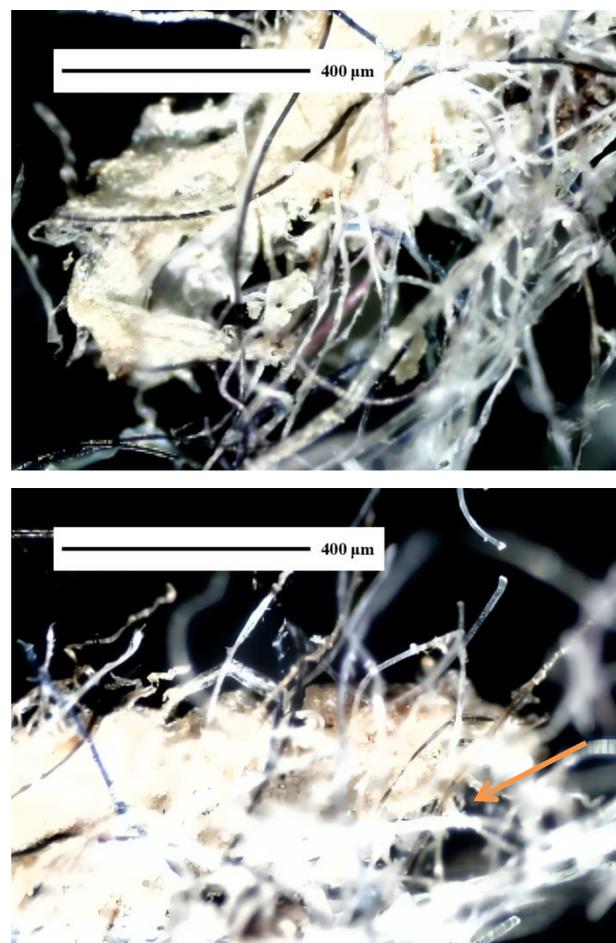


Fig. 4. Micrographs obtained for the white fiber. The arrow points to the multiple fibers that make up the microplastic.

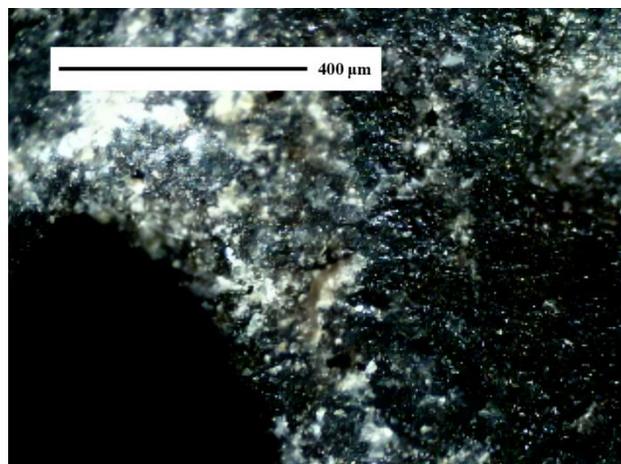


Fig. 5. Micrograph obtained for the black rubber fragment.

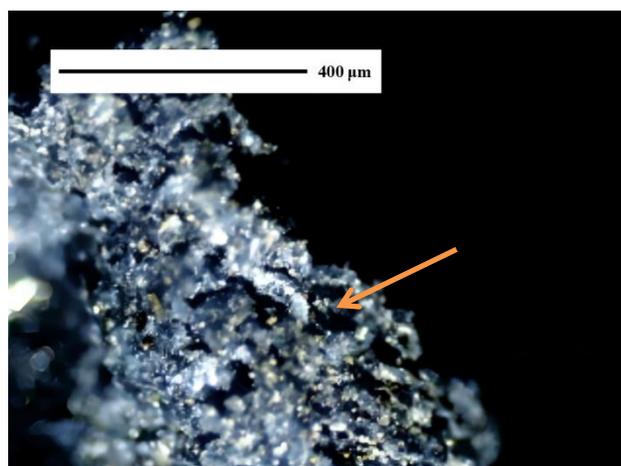


Fig. 6. Micrograph obtained for the blue foam. The arrow points to the surface irregularity of the plastic particle.

The micrographs revealed the characteristics of the fiber, showing that it is not a single piece but contain multiple fibers (Fig. 4). Likewise, high contamination was evident on the surface of the black rubber fragment, highlighting the harmful nature of microplastics as carriers of other contaminants, both organic and inorganic (Fig. 5). In the case of the blue foam, surface irregularity, and porosity were observed (Fig. 6), factors that may influence the capacity for contaminant sorption.

In Fig. 7, the respective FTIR spectra are displayed. The FTIR analyses revealed the moisture absorbed by the fiber, as evidenced by a broad band at 3334 cm^{-1} with a band at 1653 cm^{-1} , while the intense band between 1050

and 1030 cm^{-1} indicates ester groups present in the polyester fibers, which allows us to infer that this material is associated with textile fibers of clothing.

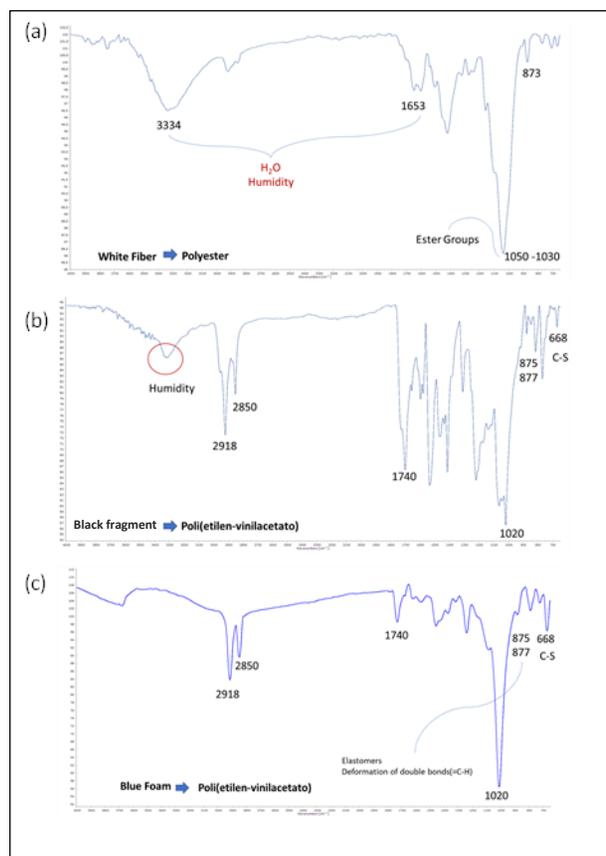


Fig. 7. FTIR spectrum for microplastics of (a) white fiber, (b) black rubber fragment, and c) blue foam.

Additionally, the FTIR spectra of fragments exhibited some common bands, such as sharp signals at 2918 and 2850 cm^{-1} assigned to the tension, symmetric, and asymmetric stretching of CH_2 groups

Signals at $875\text{-}877\text{ cm}^{-1}$ typical in elastomers due to the deformation of double bonds ($=\text{C-H}$), along with a band at 668 cm^{-1} attributed to C-S bonds. The black rubber fragment showed additional bands, indicating moisture and other bands possibly generated by contamination, as evidenced by its MO micrographs (Fig. 5). The FTIR spectra suggest the presence of poly(ethylene-vinyl acetate) foam, with the influence of signals arising from pigments used in manufacturing these plastics.

The use of microscopy as a tool for the separation and characterization of microplastics has been crucial in this study, as it has allowed for (1) to identify specific morphological and color features in plastic particles recovered from the sediment matrix that are not visible to the naked eye, (2) to observe surface alterations in the plastics due to environmental exposure, and (3) to characterize the surface of the microplastics, indicating whether they are multicomponent, rough, or porous, thus increasing their potential to become more harmful contaminants due to their ability to transport other substances. These insights provided by microscopy have significantly enhanced the better understanding of the physical changes microplastics undergo in natural environments and the extent of their degradation. These are essential for both accurate chemical analysis and determining their environmental impact.

CONCLUSIONS

The presence of plastic particles associated with the surface sediments of San Luis Beach, located in the city of Cumaná, Sucre state, was confirmed. The most abundant particles were fragments resulting from the degradation of larger plastic litter, followed by fibers, which could be linked to fishing activities in the region or the influence of wastewater carrying textile fibers. The predominant colors of the recovered particles were blue and green.

The ATR-FTIR analysis allowed the identification of the constituent polymers, revealing white polyester fibers and two foam particles, one blue and one black, composed of poly(ethylene-vinyl acetate). Furthermore, moisture and other bands potentially indicative of contaminants were detected, and the micrographs provided insights into their structure, porosity, and potential association with other contaminants commonly found in microplastics.

ACKNOWLEDGEMENT

The authors would like to thank Prof. Rossianny Rodríguez, Coordinator of the Microbiology Laboratory at UPTOS, and Dr. Iliana Jiménez for their support with the micrographs. We are also grateful to Servolab Overseas Inc. for donating the Digital Optical Microscope.

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