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Microplastics on sandy beaches of the Baja California Peninsula, Mexico

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ABSTRACT

Microplastics have become a concern in recent years because of their negative impact on marine and freshwater environments. Twenty-one sandy beach sites were sampled to investigate the occurrence and distribution of microplastics on the sandy beaches of the Baja California Peninsula, Mexico, as well as their spectroscopic characterization and morphology. Microplastics were separated using the density method and identified using Attenuated Total Reflection Fourier Transform Infrared Spectroscopy (ATR-FTIR). The mean abundance of microplastics in the samples was 135 ± 92 particles kg^{-1}, and fiber was the most abundant microplastic found in the samples, comprising 91% of the total microplastics identified. Attenuated total reflectance Fourier transform infrared spectroscopy (ATR-FTIR) analysis of the microplastics showed that the main polymers found in microplastics were polyacrylic, polyacrylamide, polyethylene terephthalate, polyesters, and nylon.

1. Introduction

In recent years, microplastic pollution has been increasingly studied by the scientific community because of its negative environmental impacts such as the hazard of ingestion by different marine organisms (plankton, fish, birds, and mammals), its use as a substrate for undesirable microorganisms, the role of microplastic in the transport of toxic compounds, and the microplastic's contribution to the bioaccumulation of persistent organic pollutants (Barnes et al., 2009; Zhang, 2017). However, the potential role of microplastics in the introduction of persistent organic pollutants (POPs) is controversial. Koelmans et al. (Koelmans et al., 2016) suggested that the effects of microplastic ingestion on bioaccumulation are probably limited in most marine habitats. However, this does not imply that microplastics do not have negative effects on marine life.

Microplastics are currently defined as plastic particles < 5 mm in size, although other studies used 1 mm as the upper limit (Kunz et al., 2016). They can be classified as primary microplastics, which are those manufactured for a specific domestic or industrial purpose, such as a scrubber in cosmetic formulations, industrial abrasives, or pellets used in the plastics industry, and secondary microplastics, which are produced by the breakdown of larger plastic items by chemical or mechanical processes (Auta et al., 2017). Microplastics can enter the marine environment through several land and sea sources. Approximately 80% of the microplastics originate from land-based sources (Browne, 2015; Yonkos et al., 2014) including rivers, stormwater runoff, transport of litter by the wind, tourism, and wastewater discharges (Avio et al., 2016), and sea-based sources including fishing, dumping, and shipping activities (Avio et al., 2016; Ribic et al., 2011). The most common microplastic shapes reported in studies are spheres, fibers, granules, and films, with fibers being the most abundant (Claessens et al., 2011; Desforges et al., 2014). Fibers with intense blue, violet, green, or red colors provide evidence of their anthropogenic origin (Stolte et al., 2015), and these are frequently made of polyester and acrylic.

Wastewater discharge has been identified as one of the main sources of microplastics in the environment and this is related to densely populated areas (Browne et al., 2011). Mason et al. (Mason et al., 2016) reported that the average microplastic content in a wastewater treatment plant (WWTP) effluent is 0.05 particles per liter, but because of the high daily volume discharged by WWTP, it has been assumed that in the US, an average of four million particles are being released per day per facility, including fibers and fragments, which are the most common types of particles found in the discharge. This is not surprising because a recent study by De Falco et al. (2018) showed that a 5-kg load of polyester fabric can release 6,000,000 to 17,700,000 microfibers, which is equivalent to approximately 0.43 to 1.27 g of microfibers. The authors also found that the number of microfibers released is determined by the fabric, detergent type, softener use, water temperature, mechanical action level, and water hardness. A more conservative

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Table 1
Location and characteristics of the sampled beaches.

Site	Name	Location (coordinates)	Population[a,e]	Beach classification	Beach characteristics
Pacific Ocean sites					
1	Playas de Tijuana	32°32′02.4"N 117°07′26.7"W	1,559,683	Urban/resort (Overdeveloped)	An intermediate beach with fine sand (median Φ = 3) and a mean slope of around 2° (Lazcano Venegas, 1997). The wave and tide height are approximately 1 and 2 m, respectively.
2	Playas de Rosarito	32°21′38.56"N 117°04′10.8"W	90,668	Urban/resort (Overdeveloped)	The coastline of beaches at Rosarito is semi-straight and partially protected by the Coronado Island with an average slope of around 2° (Rivera Lemus, 2004). The sand classification is between fine and medium sand (median Φ = 2.5). The wave and tide heights are approximately 1 and 2 m. This beach can be classified as intermediate.
3	La Misión	32°05′36.2"N 116°53′02.3"W	733	Rural (undeveloped)	This is an open beach with an average slope of around 2.4°, The approximate length is 1 km and the sand can be classified as fine sand (median Φ = 3). The beach is characterized by its strong rip currents (Lugo Ibarra, 2004).
4	Ensenada	31°50′21.5"N 116°36′41.9"W	192,550	Urban beach/resort (Overdeveloped)	A gentle sloping mesotidal beach with a slope around 1° (Ruiz de Alegria-Arzaburu et al., 2016) with medium sand (median Φ = 2.1).
5	Punta Banda	31°45′23.1"N 116°37′55.9"W	45	Urban beach/no resort (developed)	It is located in an open bay with a gentle slope of 1.5°, very fine to fine sand (median Φ = 3.4) and an intermediate beach morphology (Jimenez Perez, 1988)
6	Vicente Guerrero	30°42′22.6"N 116°02′14.8"W	10,635[b]	Rural beach (Underdeveloped)	This is an open beach exposed to strong waves. It has a very irregular surface with parallel and normal channels to the beach line and shallow pools. The beach is located south of an intermittent stream mouth. The beach can be classified as intermediate with very fine sand (median Φ = 3.4).
7	Santa Maria	30°23′57.5"N 115°54′47.8"W	NA	Rural beach (underdeveloped)	An open beach with very fine sand (median Φ = 3.4), and a tide around 2 m with high energy waves. The beach has an approximate slope of 5° (Carranza-Edwards et al., 1998).
8	El Socorrito	30°19′04.2"N 115°49′32.5"W	29	Rural beach (underdeveloped)	An open beach with very fine sand with traces of very coarse gravel (median Φ = 3.4). The approximate slope of the beach is around 4°.
9	Valle Tranquilo	30°14′10.1"N 115°47′41.6"W	NA	Rural beach (underdeveloped)	An open and narrow beach of around 50 m facing eroded bluffs. The sand is very fine (median Φ = 3.4) with coarse gravel.
10	Guerrero Negro	28°01′53.8"N 114°06′58.8"W	13,054[c]	Rural beach/no resort	The beach has very fine sand (median Φ = 3.3) and is located in a semi enclosed bay with low energy waves. The tide height is 2.4 m.
11	Todos los Santos	23°25′24.3"N 110°13′48.0"W	5,148[d]	Rural beach (underdeveloped)	A steep slope beach (around 20° in hurricane season) with high energy waves all year round, classified as reflective (Lira Beltran, 2009) with medium sand (median Φ = 1.6) that is slightly gravelly.
12	Cabo San Lucas	22°53′6.2"N 109°54′20.9"W	76,032	Urban beach/resort (Overdeveloped)	A beach with a slope between 2.5° and 5.8° and medium sand (median Φ = 1.5) that is slightly gravelly. It is considered a reflective beach (Navarro Lozano et al., 2009).
Gulf of California sites					
13	San Felipe	31°01′39″N 114°50′07″W	16,702	Urban beach/resort (Overdeveloped)	Beach with medium sand (median Φ = 1.5) and mean slope about 1.2°. The tide height is 6.6 m.
14	La Perla	30°56′29.7″N 114°43′50.6″W	NA	Rural beach (Underdeveloped)	Beach with medium sand (median Φ = 2.0) and a mean slope about 1.2°. The tide height is 6.6 m. A wastewater discharge was observed in the vicinity of the sampling site.
15	Playa La Gringa	29°02′19.9″N 113°32′56.1″W	NA	Rural beach (underdeveloped)	The beach is sheltered in a cove with low energy waves (tide height = 2.8 m) and fine sand (median Φ = 2.5).
16	Bahía de los Ángeles	28°57′11.7″N 113°33′27.4″W	543	Urban beach/no resort (developed)	A beach (tide height = 2.8 m) sheltered in an open bay with low energy waves and an approximate slope of 4.60° (Carranza-Edwards et al., 1998). The sand in this beach is classified as fine sand (median Φ = 2.7).
17	Ejido San Lucas	27° 13′02.8″N 112°12′50.7″W	606	Rural beach (underdeveloped)	The beach sheltered in a cove, fine sand with biogenic material (median Φ = 2.9), tidal height of 1.5 m and low energy waves.
18	Loreto	26° 00′24.69″N 111°20′19.3″W	14,724	Urban beach/no resort (developed)	The beach is located in the Loreto Bay with very fine sand (median Φ = 3.3). It has a low slope (0.9°) and tide height of around 1.5 m (Navarro Lozano, 2009).
19	El Requesón Mulegé.	26°38′18.4″N 111°49′53.2″W	NA	Rural beach (underdeveloped)	The beach is located in a semi enclosed bay with medium sand (median Φ = 1.6) with biogenic material. The energy of waves is low.
20	La Paz	24°09′49.1″N 110°19′01.3″W	251,871	Urban beach/resort (overdeveloped)	The beach is sheltered behind a natural sandy barrier with fine sand and biogenic material (median Φ = 2.4), the beach can be classified as reflective with terrace at low tide (Torres Alfaro, 2010).
21	La Balandra	24°19′18.4″N 110°19′26.9″W	NA	Rural beach (underdeveloped)	Beach sheltered in a cove with slope of 5° and fine sand with biogenic material (median Φ = 2.9). Classified as intermediate beach with sand bars (Torres Alfaro, 2010).

NA, not applicable, meaning that the beach is located in an unpopulated site.
[a] Permanent population of the city, town or settlement located by the beach, except for those sites indicated in the table.
[b] The population shown is for a settlement located around 5 km from the site.
[c] The population shown is for a settlement located around 12 km from the site.
[d] The population shown is for a settlement located 2.5 km from the site.
[e] INEGI (INEGI (Instituto Nacional de Estadística y Geografía), 2010) and Gobierno del estado (Gobierno del estado de Baja California, 2015).

figure of microfiber release by washing was given by Napper and Thompson (Napper and Thompson, 2016), and they estimated that over 700,000 fibers could be released from a 6-kg acrylic wash load. Some estimates indicated that laundering synthetic textiles contributes about 35% of the total microplastics released to the marine environment (Boucher and Friot, 2017).

Microplastics on beaches have also been linked to tourism activities (Stolte et al., 2015; Yu et al., 2016). These tourism activities use items made with plastics that are used in water sports such as kayaking, snorkeling, and scuba diving. Moreover, tourists use swimming suits