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Baseline

Microplastics in tourist beaches of Huatulco Bay, Pacific coast of southern Mexico

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ABSTRACT

The presence and impacts of plastic marine debris (PMD) have been documented in the oceans worldwide, and they deserve special attention. This study is the first to report the presence of microplastics in tourist beaches located in Huatulco Bay, southern Mexico. A total of 70 beach sediment samples (for 2 distinct seasons) were collected from Huatulco Bay in April 2013 and December 2014. The samples were subsequently extracted by scanning electron microscopy (SEM) to identify the fibrous microplastics (diameter < 5 mm). The maximum number of fibrous materials was found in April 2013 and December 2014 in the Rincón Sabroso beach (48/30 g sediment) and the Cuatunalco beach (69/30 g sediment), respectively. Overall, a high amount of microplastics is present in the Conejos, Tangolunda, Santa Cruz, and San Agustin beaches. The microplastics are mainly derived from tourism-based activities and effluents discharged from the hotels and restaurants located along the beaches.

In the Anthropocene age, the use of plastic has been considered to provide more advantages than the traditional materials as it provides numerous societal benefits. Plastics are lightweight, durable, strong, economic, and hence useful for a wide range of manufacturing processes. High resistance to aging and non-biodegradable properties of plastics attribute to their hazardous nature (Derraik, 2002). Since the 1950s, the annual plastic production has increased dramatically from 1.5 million tons to approximately 280 million tons in 2011 (Plastics Europe, 2012), and there has been a synchronous global increase in plastic production and plastic litter. Approximately 60–80% of marine debris and about 90% of floating debris worldwide are plastics (Gordon, 2006).

Smaller plastic debris known as "*microplastics*" (diameter < 5 mm), which are often not visible to the naked eye, pose a great threat and are scientifically one of the major environmental consequences of increased plastic use. Microplastics are sourced by their direct release from scrubs and abrasives used in household activities, personal care products, and synthetic textiles, and by the fragmentation of larger plastics with or without the presence of ultraviolet light radiation (UNEP, 2013). Primary sources of microplastics are microscale products. Secondary sources result from the fragmentation of macroplastics by photodegradation, oxidation, and mechanical abrasion (Andrady, 2003, 2005; Browne et al., 2007; Cole et al., 2011; Wright et al., 2013). Because of the persistence and ubiquitous nature of microplastics, they act as potential vectors for the transfer and exposure of persistent organic pollutants to marine organisms (Hidalgo-Ruz and Theil, 2013). These plastic debris attract the encrusting organisms and can be easily ingested or entangled by various marine organisms (Bockstiegel, 2010; Martins and Sobral, 2011a, 2011b; Von Moos et al., 2012).

Plastics found in beach environments are chemically weathered, and they have mechanically eroded surface textures. Beaches act as an excellent depositional site for plastic debris (Corcoran et al., 2009). The presence of plastic fragments alters permeability of beach sediments and affects heat transfer between sediment grains (Carson et al., 2011). Similarly, the presence of large amounts of white microplastics in the beach sands stimulates various invertebrates for their settling and colonization, resulting in their ingestion, as they resemble a prey (Katsanevakis et al., 2007). The pivotal status of microplastics in the global environmental dimension is considered deleterious, especially for marine environments, because of their high resistance to aging and slower rate of biodegradation.

The extensive beaches along Huatulco Bay of the Pacific coast of Mexico are prominent tourist destinations, gaining approximately 65%

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of main income from tourism-based activities by fetching >300,000 tourists every year (Huerta and Sánchez, 2011). In the beaches of Huatulco, the huge amounts of microplastics are attributed to the high influences of the sewage disposed by the stationed cruise vessels, hotels, and tourist activities fringing the bays of Huatulco. To date, there are no reports on the presence of microplastics in the sediments of this Mexican coastline. Hence, this is the first study to document the presence of microplastics in the sediments of tourist beaches located along Huatulco Bay of southern Mexico.

The rugged terrain of Huatulco Bay divides the approximately 35-km coastline into nearly nine small bays and 36 beaches. In this study, beaches were chosen according to their accessibility and presence of tourist activities. Samples were collected considering two distinct seasons. The first one was in April 2013 immediately after the Easter week and the second sampling was carried out in December 2014 (Christmas week) to observe the impact of tourism on plastic debris accumulation. A total of 70 sediment samples (35 in each season) were collected from: (1) Bahia Conejos [S. Nos. 1–6]; (2) Bahia Tangolunda [S. Nos. 7–11]; (3) Bahia Chahue [S. Nos. 12–16]; (4) Bahia Santa Cruz [.S. Nos. 17–20]; (5) Bahia Órgano [S. Nos. 21]; (6) Bahia Maguey [S. Nos. 22]; (7) Bahia Cacaluta [S. Nos. 23]; (8) Bahia Chahacual [S. Nos. 24–27]; and (9) Bahia San Agustín [S. Nos. 28–31], El Arenal [S. Nos. 32–33], Boca Vieja [S. Nos. 34], and Cuatunalco [S. Nos. 35] (Fig. 1). Sediment samples were collected along the high tide line where the flotsam accumulates, and these samples were air-dried in laboratory (at room temperature) for further analyses.

The analytical procedure includes density separation method modified by Thompson et al. (2004). It was followed by filtration and visual inspection. The first step of analysis involved treatment of 30-g sediment sample with 30% H_2O_2 overnight to remove natural organic debris, and this pretreatment did not affect any plastic particles. The floating technique was used to extract microplastics from the beach sediments. Because most of the plastics have specific gravity >1, a zinc chloride solution (density, 1.58 g/cm^3) was introduced into the sample, which made the microplastics to float (Liebezeit and Dubaish, 2012; Imhof et al., 2013; Nuelle et al., 2014). The floating microplastics were filtered using a 1.2-μm nitrocellulose filter paper, subsequently air-dried in the laboratory, and then observed under stereomicroscope to estimate

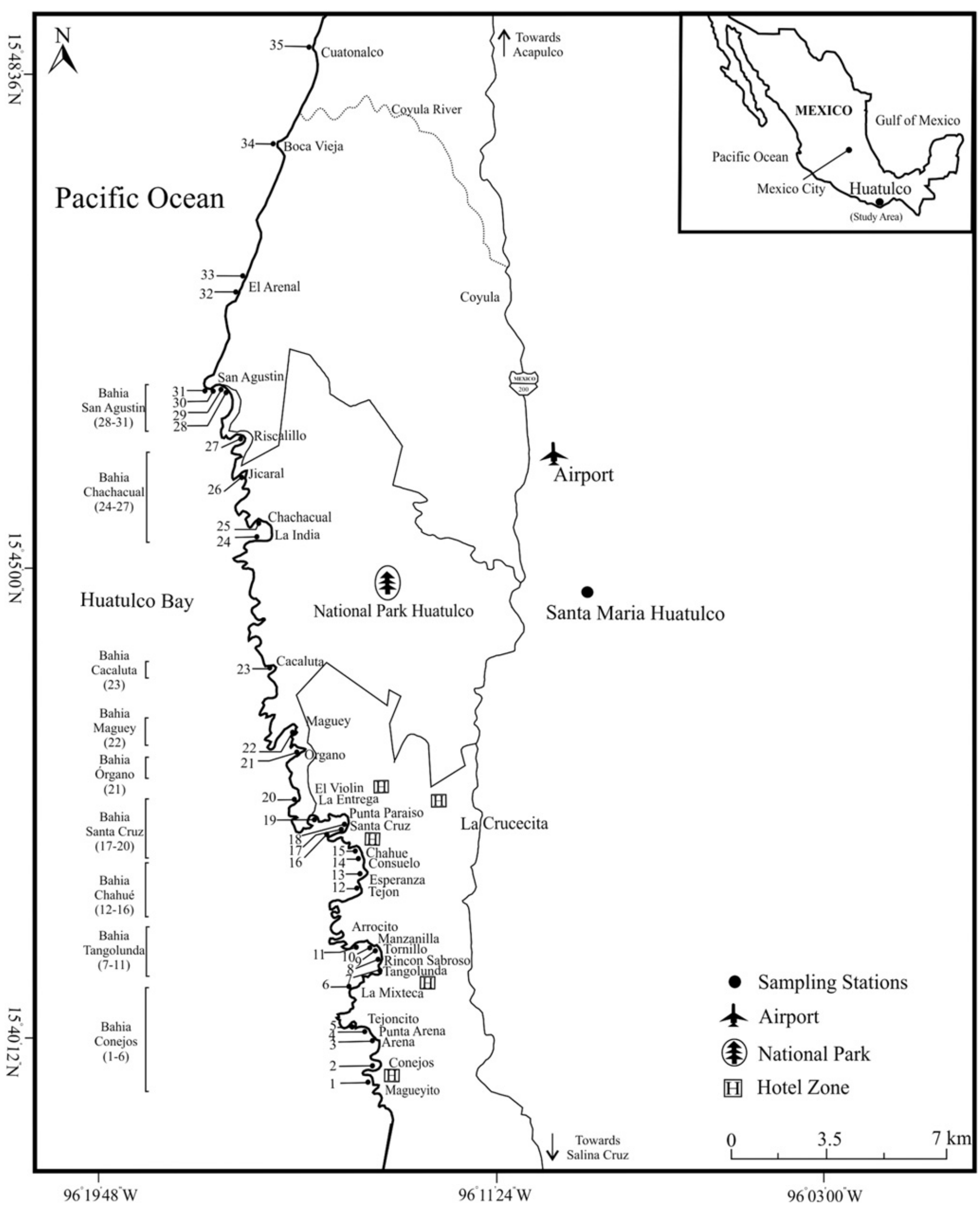

Fig. 1. Map illustrating the sampling locations of tourist beaches and bays in Huatulco Bay, Mexico.

their surface structure, diameter, and size. Later, the selected microplastics were observed under a scanning electron microscope (HRSEM – Auriga) and confirmed as plastic materials (60–72% of C) by inbuilt EDAX.

Fibrous microplastics were found in all the sampled beaches and their abundance was determined as numbers per 30 g of dried weight sample (n/30 g DW) (Fig. 2a). In April 2013, the amount of fibrous microplastics (n/30 g DW > 20) was found to be higher at beach stations 8, 10, 32, and 35. The maximum number of fibers was observed at station 8 (n/30 g DW = 45). Similarly, the maximum number of microplastics (n/30 g DW > 20) was found at stations 4, 5, 13, 20, 21, 30, 31, and 35 during the Christmas week in December 2014, which is the peak season of tourism in Mexico.

The higher number of microplastics in the beaches is mainly due to the presence of adjacent hotels and sewage disposals (effluents), which form the potential source of plastic debris in these region (Browne et al., 2011). In this study, some of the beaches located at the north are characterized by gentle waves. Tourism in these beaches is associated with water sports, scuba diving, and snorkeling such as kayaking and motor gliders. The source of plastic materials in these beaches has dual origin: from land-based effluents and tourist activities (Cole et al., 2011; Derraik, 2002). A higher amount of microplastics is also directly linked to the increased number of tourists using swimming suits and UV light-protecting clothes made of synthetic fibers. Specific sites like stations 20 and 21 (El Violín and Órgano beaches of the bays of Santa Cruz and Órgano) had higher amount of microplastics, which is associated with numerous hotels (laundry draining), restaurants, and tourist boats (made of plastic). The docking of larger cruise vessels during peak tourist seasons also aggravates the existing load. Comparison of the results obtained from both the sampling seasons (April and December) indicates the spatial variation and impact of tourism in several beaches, specifically at stations 3–7, 12, 13, 15–17 and at majority of sites located between stations 20 and 35 (Fig. 2). In April 2013, microplastics were absent at station 28, one of the beaches of San Agustin Bay. However, the abundance of microplastics increased to 11 fibers/30 g DW in the same beach in December 2014, which clearly directs the source to tourism and other recreation-based activities together with the changes in water current movements and heat transfer (Carson et al., 2011).

The multicolored fibrous microplastics observed in all the beach stations are shown in Fig. 2b. Five fiber colors were recorded and their abundance was in the following descending order: white > black > blue > red > light brown. The effect of color on the bioavailability of microplastics is significant and may favor their intake by marine organisms, as they resemble a prey (Shaw and Day, 1994; Cózar et al., 2014; Wang et al., 2016). The presence of colored microplastics clearly suggests that they are of synthetic origin and may be enriched with trace organic substances, which require further detailed studies.

Fig. 3a–f shows an outlook of varying thickness of fibrous microplastics present in the study area. The minimum and maximum thicknesses of fibers were 3.038 and 20.01 μm, respectively. The average thickness of fibrous microplastics ranged from 4.247 to 50.2 μm, and the total length showed a wide range of variations (0.004266–4.491 μm). SEM images show the disintegration of microplastics (Fig. 4a–c), which occurs due to photo, thermal, or biological degradation

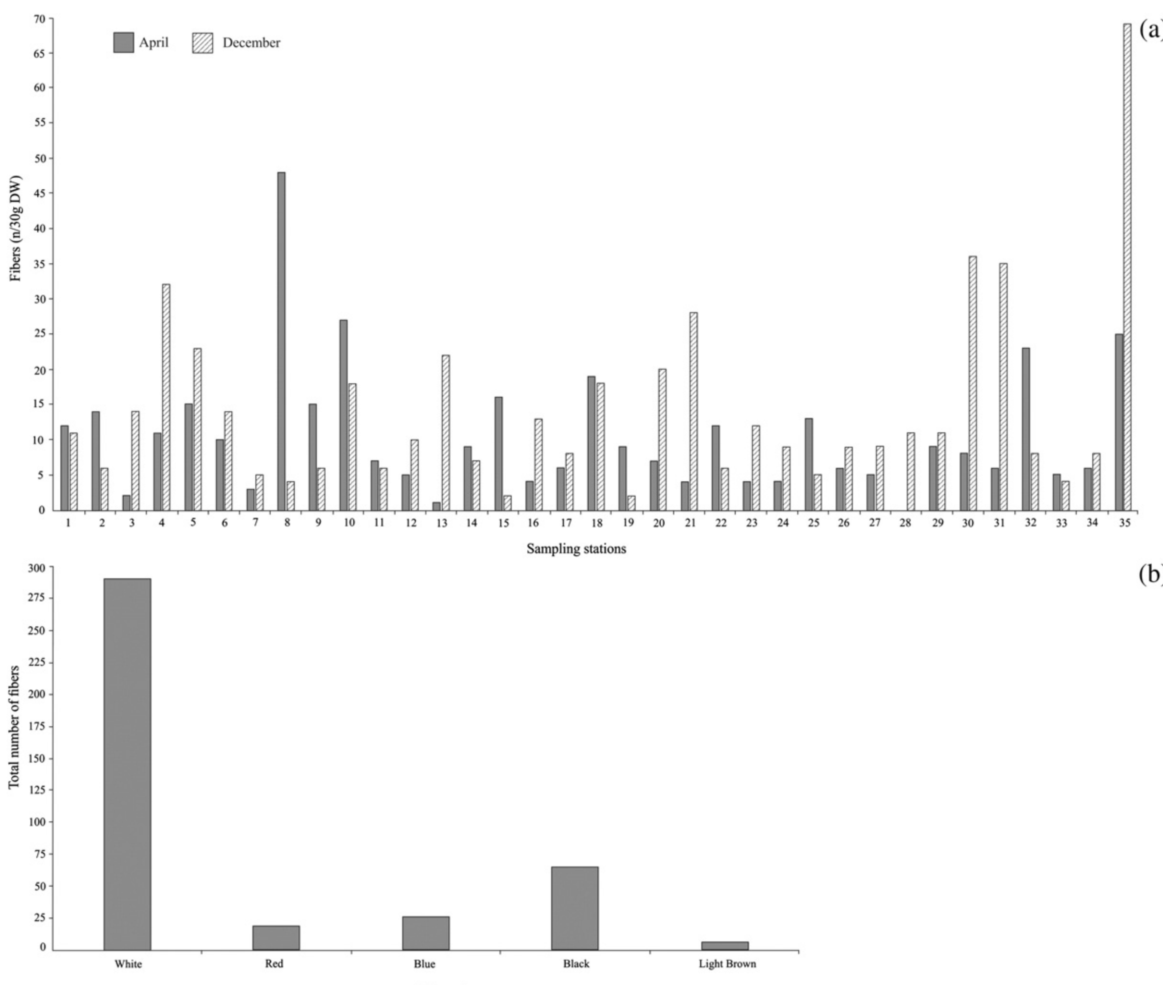

Fig. 2. a–b. Distribution and color of microplastics encountered in the tourist beaches of Huatulco Bay, Mexico.

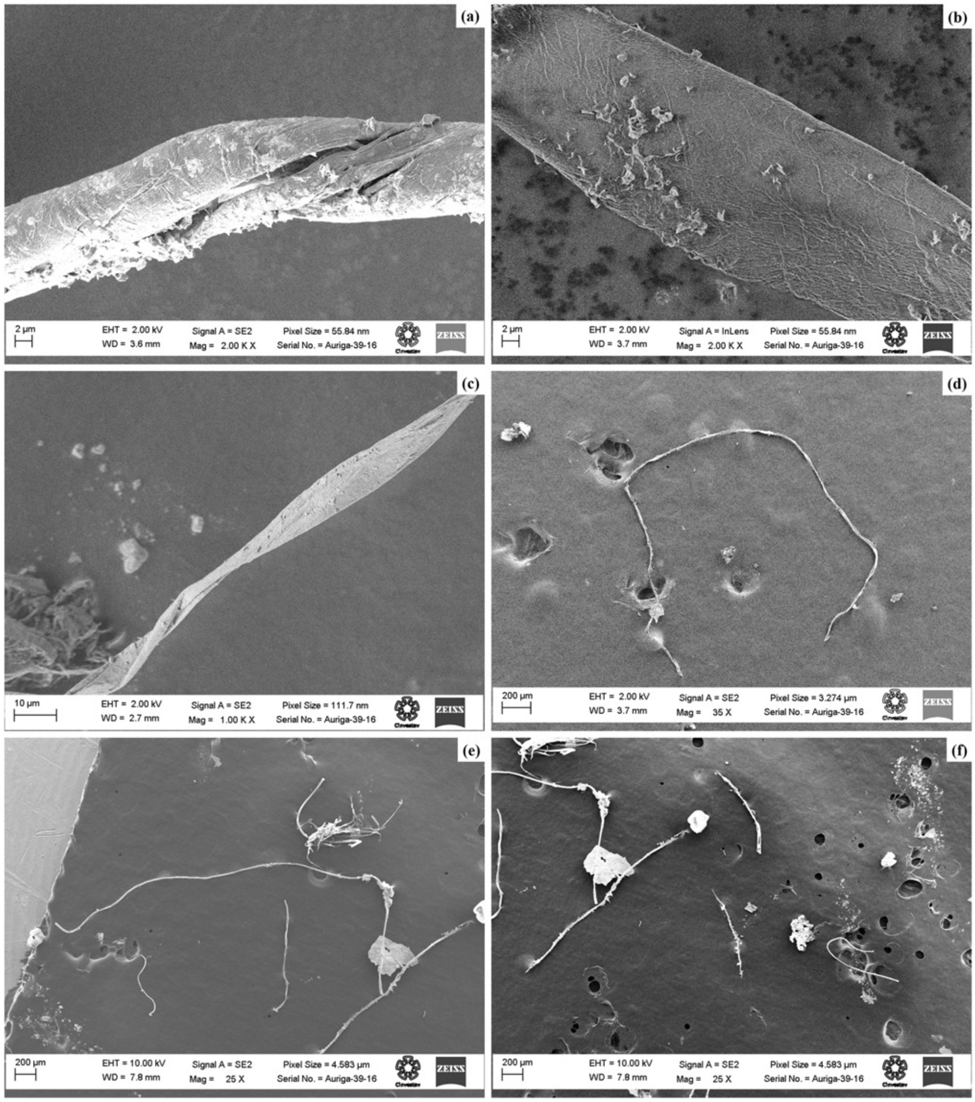

Fig. 3. a–f. SEM images showing the thickness of fibrous microplastics in the beach sediments of Huatulco Bay, Mexico.

(Gregory and Andrady, 2003; Shah et al., 2008). It has already been stated that the land-based microplastics disintegrate rapidly than those floating on the water because of prolonged exposure of solar radiation and subsequent increase in temperature (Pegram and Andrady, 1989; Cooper and Corcoran, 2010). Fig. 4d–e shows the presence of microplastic materials originating specifically from tourism-based activities; this was confirmed through online EDAX composition analysis that revealed the maximum concentration of carbon (>60%).

Considering the upturn, the worldwide distribution of microplastics in beach sediments is shown in Table 1. The existence of microplastics in bays and beaches of Huatulco Bay (Mexico) was higher than that in the coastal beaches of Singapore in Asia, Plymouth, North Sea, English Channel, and East Frisian Islands of Europe. However, the beaches of Africa, America, India, South Korea, Belgium, Portugal, Slovenia, and the German Baltic coast have higher amounts of microplastics than Huatulco Bay.

The present study is important because it is the first report to provide evidence of microplastics along the Huatulco beaches that are mainly derived from intensive tourist activities. Even though this is a baseline report, it is significant in order to evaluate the effect of tourism and the amount of plastic debris (in the form of polyesters, polyethylene terephthalate, polyethylene, and polystyrene) accumulation along the shores, which would be a great menace for the overall survival of marine organisms. Hence, there is urgent need to adopt the following strategies to mitigate the problem: (i) increasing awareness of the common people regarding environmental misuse of plastic products, (ii) improving sewage treatment infrastructure, and (iii) developing suitable methods for the removal of microplastics from point sources such as hotels, restaurants, and fishing activities. In addition, the most significant potential ways to reduce the impact of microplastics in beaches and coasts are to scale down the use of plastic materials and to implement smart recycling methods.

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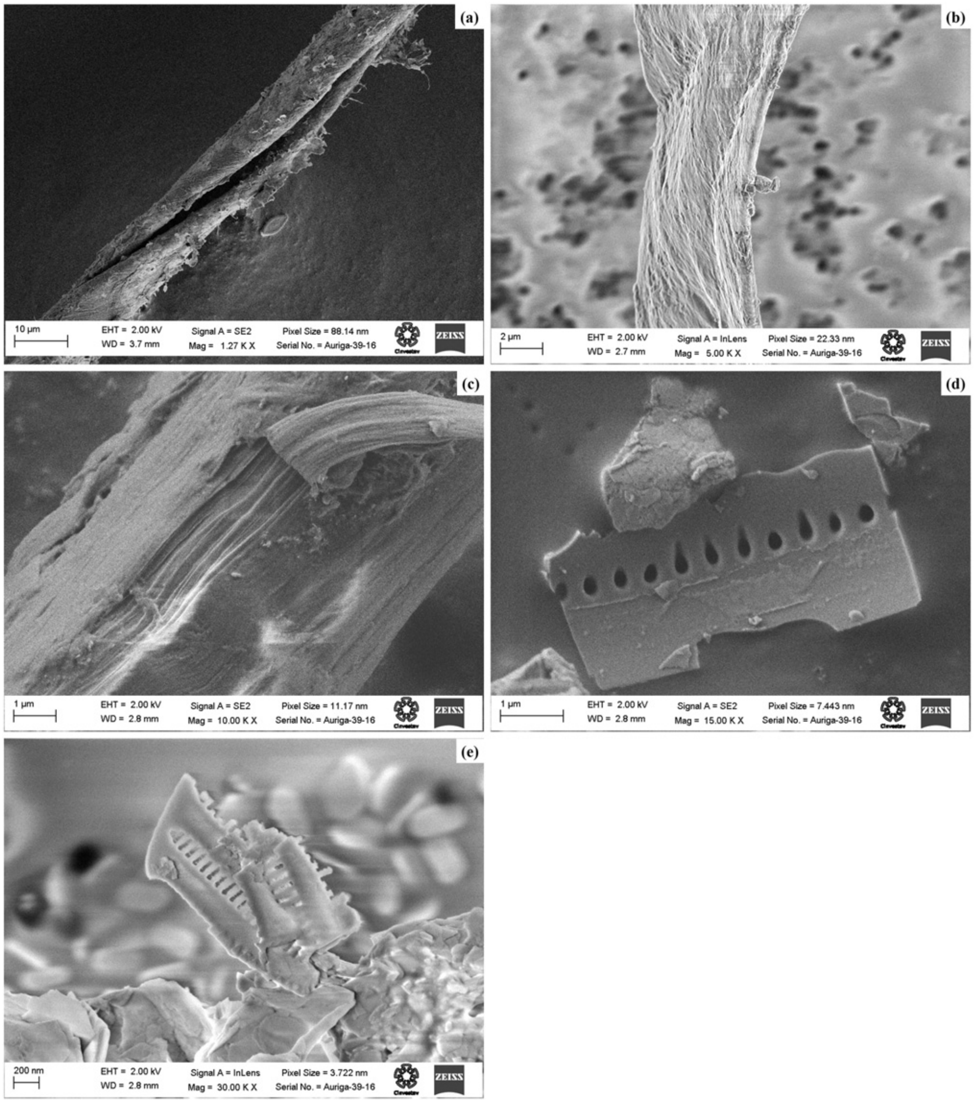

Fig. 4. a–e. SEM images showing disintegration of microplastics along the surface textures in sediments of Huatulco Bay, Mexico.

Table 1
Worldwide abundance of microplastics in beach sediments.

Continent	Location	Measured abundance	References
Africa	Canary Island beaches	<1 ≥ 100 g/L	Baztan et al., 2014
America	Hawaiian archipelago beaches	541–18,559 items/260 L	McDermid and McMullen, 2004
	Fernando de Noronha beach, Brazil	60 items/m^2	Ivar do Sul et al., 2009
	Beaches in SE Pacific, Chile	<1–805 items/m^2	Hidalgo-Ruz and Theil, 2013
	Halifax Harbor beach, Nova Scotia	20–80 fibers/10 g	Mathalon and Hill, 2014
Asia	Singapore beaches	0–4 items/250 g DW	Ng and Obbard, 2006
	Beaches of Mumbai, India	10–180 items/m^2	Jayasiri et al., 2013
	South Korean beaches	56–285,673 items/m^2	Kim et al., 2015
Europe	Plymouth, UK	0.4 fibers/50 mL	Thompson et al., 2004
	UK North sea	0.2–0.8 fibers/50 mL	Browne et al., 2011
	UK English channel	0.4–1 fibers/50 mL	Browne et al., 2011
	Belgian coast	92.8 items/kg dry	Claessens et al., 2011
	Portugal beach	133.3 items/m^2	Martins and Sobral, 2011a, 2011b
	East Frisian Islands, Germany	1–14/10 g/DW	Liebezeit and Dubaish, 2012
	Slovenia beach	177.8 items/kg DW	Laglbauer et al., 2014
	German Baltic coast		
	Rostock sediment samples	41.79–532.19 N_F/kg	Stolte et al., 2015
	Rügen sediment samples	17.2–73.3 N_F/kg	Stolte et al., 2015
Present study			
America	Bays and beaches of Huatulco, Mexico		
	April 2013	0–48/10 g DW	
	December 2014	2–69/10 g DW	

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