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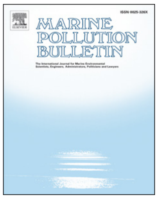

Microplastic pollution on Caribbean beaches in the Lesser Antilles

Thijs Bosker[a,b,*], Lucia Guaita[a], Paul Behrens[a,b]

[a] Leiden University College, Leiden University, P.O. Box 13228, 2501 EE The Hague, The Netherlands
[b] Institute of Environmental Sciences, Leiden University, P.O. Box 9518, 2300 RA Leiden, The Netherlands

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ABSTRACT

Here we investigate microplastics contamination on beaches of four islands of the Lesser Antilles (Anguilla, St. Barthélemy, St. Eustatius and St. Martin/Maarten). These islands are close to the North Atlantic subtropical gyre, which contains high levels of microplastics. On average 261 ± 6 microplastics/kg of dry sand were found, with a maximum of 620 ± 96 microplastics on Grandes Cayes, Saint Martin. The vast majority of these microplastics (> 95%) were fibers. Levels of microplastics differed among islands, with significantly lower levels found in St. Eustatius compared to the other Islands. No difference in microplastic levels was found between windward and leeward beaches. Our research provides a detailed study on microplastics on beaches in the Lesser Antilles. These results are important in developing a deeper understanding of the extent of the microplastic challenge within the Caribbean region, a hotspot of biodiversity.

1. Introduction

Microplastics (pieces of plastics < 5 mm) are a group of contaminants of emerging concern, which are now ubiquitous in the environment (Andrady, 2011; Cole et al., 2011; Lots et al., 2017; Nizzetto et al., 2016). Two types of microplastics are commonly distinguished in the literature: primary and secondary microplastics. Primary microplastics are added to household products or used in industry, and are often uniform in shape (Browne et al., 2011; Rochman et al., 2015; van Wezel et al., 2015). Secondary microplastics are formed when larger pieces of plastic break down in the environment due to ultraviolet (UV) exposure and weathering (Andrady, 2011). This results in fragmentation into smaller pieces of plastics (Andrady, 2011; Cole et al., 2011). Consequently, there is a large range in physico-chemical characteristics of microplastics. They exist in different shapes (e.g., fibers, microspheres, fragments) (Cole et al., 2011; Ivar do Sul and Costa, 2014; Naidoo et al., 2015; Wright et al., 2013), size ranges (from the nano- to mm-range) (Andrady, 2011; Cole et al., 2011; Costa et al., 2010; Ivar do Sul and Costa, 2014; Ter Halle et al., 2016; Wright et al., 2013) and chemical constituents (e.g., polyethylene, polypropylene, polyvinylchloride and polystyrene) (Andrady, 2011; Browne et al., 2010; Engler, 2012).

Microplastics are easily ingested by organisms due to their small size (Cole and Galloway, 2015; Desforges et al., 2015; Setälä et al., 2014; Van Cauwenberghe et al., 2015; Vendel et al., 2017). In addition, laboratory experiments have found adverse impacts of microplastics, including: decreased survival and reduced fecundity in the marine copepod *Tigriopus japonicus* (Lee et al., 2013); decreased reproductive output in the marine copepod *Calanus helgolandicus* (Cole et al., 2015); anomalous embryonic development in the sea urchin *Lytechinus variegatus* (Nobre et al., 2015); reduced feeding behavior in brine shrimp *Artemia franciscana* larvae (Bergami et al., 2016); reduced body mass in the langoustine *Nephrops norvegicus* (Welden and Cowie, 2016); and, tissue damage in the blue mussel *Mytilus edulis* (von Moos et al., 2012).

The marine environment has been identified as a major sink for microplastics (Cole et al., 2011; Ivar do Sul and Costa, 2014; Woodall et al., 2014). An important factor influencing plastic distribution and accumulation in oceans are ocean currents (Cózar et al., 2017; Law et al., 2010). For example, in the North Atlantic subtropical gyre levels of microplastics exceed 100,000 pieces/km^2 (Eriksen et al., 2014; Law et al., 2010). The North Atlantic subtropical gyre is located close to the Caribbean region, which is the location for this study. A study on microplastic levels in Caribbean surface waters between 1986 and 2008 found an average distribution of 1414 items/km^2, with a peak of 580,000 items/km^2 in May 1997 on the eastern-side of the Bahamas (Law et al., 2010).

Very few studies have investigated microplastics on Caribbean beaches (Ivar Do Sul and Costa, 2007; Monteiro et al., 2018). A study on Columbian beaches, found limited plastics (an average of 3 particles/m) (Acosta-Coley and Olivero-Verbel, 2015). Three earlier studies, focusing on plastic fragments and pellets, found relatively high levels, but in these studies no size definition is provided on the fragments identified (Debrot et al., 1999; Gregory, 1983; Wilber, 1987). In addition, studies on meso- and macroplastics on Aruba (Southern Caribbean)

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* Corresponding author at: Leiden University College, Leiden University, P.O. Box 13228, 2501 EE The Hague, The Netherlands.
E-mail addresses: t.bosker@luc.leidenuniv.nl (T. Bosker), l.guaita@umail.leidenuniv.nl (L. Guaita), p.a.behrens@luc.leidenuniv.nl (P. Behrens).

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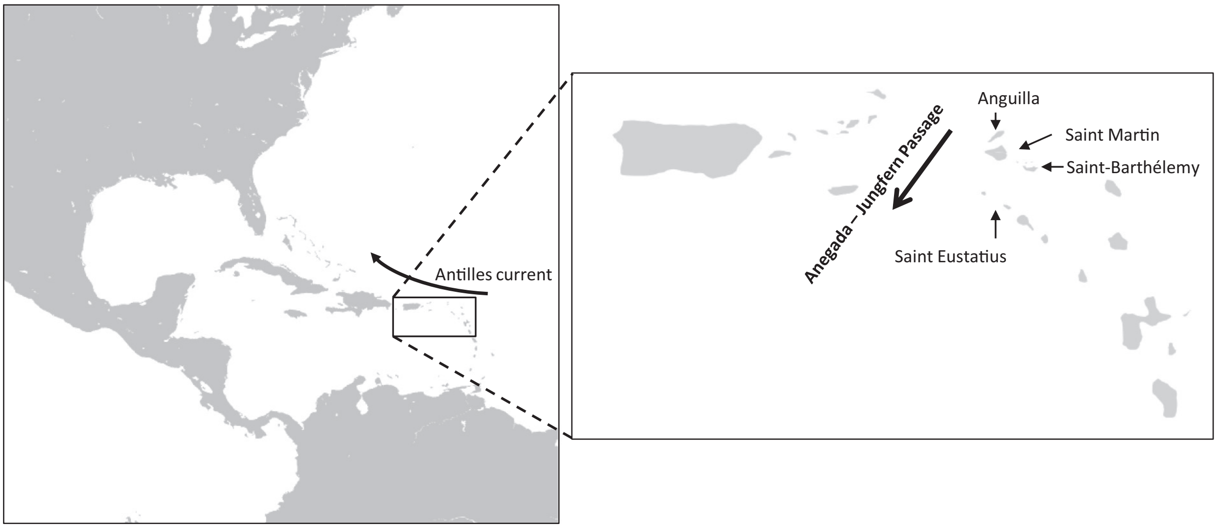

Fig. 1. Figure showing the four Island in the Lesser Antilles region samples, and key currents acting in the proximity of the sampling locations.

found significant variations in composition and quantity of plastics between windward and leeward beaches on the Island (de Scisciolo et al., 2016).

The aim of this study was to increase our understanding on microplastics levels in beach sediment in the Caribbean region. To this end we investigated the level, distribution, and characteristics of microplastics on four Islands of the Lesser Antilles, located in close proximity to the North Atlantic subtropical gyre. This research will contribute to the knowledge on microplastics distribution in this region, ultimately increasing our understanding on how to develop optimal coastal management regulations to protect these ecosystems (Rochman, 2016). This is of importance, as this region has an exceptionally rich biodiversity, making it a biodiversity hotspot for both terrestrial and marine ecosystems (Myers et al., 2000).

2. Materials and methods

2.1. Study site

This study was conducted on four volcanic islands of the Lesser Antilles: Anguilla, St. Barthélemy, St. Eustatius and St. Martin (Fig. 1), which are located near the North Atlantic subtropical gyre. Part of the South Atlantic water mass is deflected towards the Leeward Islands and enters the Caribbean Sea through the Anegada–Jungfern Passage (Fratantoni et al., 1997; Osborne et al., 2014) (Fig. 1). Although the prevailing winds on the Lesser Antilles are east-north-easterly, there is a bimodal annual pattern, with similar frequencies for easterly and east-north-easterly winds (Chadee and Clarke, 2014). The Caribbean region is a highly exposed area to seasonal extreme events such as tropical hurricanes, which have intensified and occurred with a higher frequency in recent years (Bernal et al., 2016).

2.2. Sampling and extraction procedures

2.2.1. Beach sampling

A total of 21 beaches over the four islands were sampled during June 2016 (Fig. 2; Table S1). For each beach, samples were collected on the same day. Prior to sampling, site selection was conducted using an online mapping program (www.mapcustomizer.com). Accessibility was then checked using satellite imagery (Google Earth version 7.1). For each location GPS coordinates were recorded using a mobile phone application (EzgApps GPS Coordinates Finder version 1.2; projection WGS 84 Web Mercator).

Beach sampling methods were based on a standard operating procedure developed by Besley et al. (2017). In brief, for each sampling location, the high-tide line (or strandline) was first identified by assessing the end of wet sand marks, debris areas or shell deposition areas. Five samples were collected at each beach, with 20 m between sampling locations, using a 50 m measuring tape. A 0.25 m^2 quadrat was positioned at the center of each of the interval points. Sand from the top 5 cm was collected from the corners and center of the quadrat using a metallic spoon and five rulers. Next, the sand was sieved through a 5 mm metallic sieve and collected in a clean plastic zip-lock bag. The sampling equipment was then rinsed in sea water and reused for further samples. Details on the sampling beaches, including beach type, beach management and other features are summarized in Table S2.

2.2.2. Extraction

Extraction was conducted at the laboratory facilities of the Caribbean Netherlands Science Institute (CNSI) on St. Eustatius. A density separation method was used, as described in Besley et al. (2017). Briefly, 100 g (wet weight) of sand was dried at 60 °C for 48 h. Next, the 50 g (dry weight) of sand was added in a conical flask containing 200 mL of fully-saturated NaCl solution (358.9 g salt/L). The NaCl solution was filtered using a 47 mm Millipore 0.45 μm filter paper (Fisher Scientific, the Netherlands) to remove impurities and debris deriving from the salt. This suspension was then spun at 900 rpm for 2 min using a magnetic stirrer. The sand was left to settle for a minimum of 8 h.

After settling, the supernatant was filtered through a 0.45 μm pore filter paper using a vacuum pump. Approximately 100 mL of the supernatant was poured into the vacuum pump while slowly rotating the conical flask to prevent floating material from sticking to the sides of the flask. The filter paper was then moved to a clean Petri dish and stored. The extraction process was repeated three times for each sample.

To avoid contamination, all equipment used during the extraction process was rinsed with distilled water before usage. All Petri dishes for storage of samples were wiped (Kimberly Clark cellulose wipe, Fisher Scientific, the Netherlands). During the extraction process, all equipment and vessels were covered when they were not in use.

2.2.3. Visual identification

The identification of microplastic fibers and particles was performed by following the guidelines developed by Hidalgo-Ruz et al. (2012). For the identification of fibers, three guiding principles were followed to determine whether they were plastics: 1) consistently clear and