Marine Pollution Bulletin 109 (2016) 178–183

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Abundance and characteristics of microplastics in beach sediments: Insights into microplastic accumulation in northern Gulf of Mexico estuaries

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ARTICLE INFO

Article history:
Received 29 February 2016
Received in revised form 1 June 2016
Accepted 2 June 2016
Available online 7 June 2016

Keywords:
Microplastics
Plastic
Pollution
Marine debris
Marine litter
Gulf of Mexico

ABSTRACT

Microplastics (plastic debris smaller than 5 mm) represent a growing concern worldwide due to increasing amounts of discarded trash. We investigated microplastic debris on sandy shorelines at seven locations in a northern Gulf of Mexico estuary (Mobile Bay, AL) during the summer of 2014. Microplastics were ubiquitous throughout the area studied at concentrations 66-253× larger than reported for the open ocean. The polymers polypropylene and polyethylene were most abundant, with polystyrene, polyester and aliphatic polyamide also present but in lower quantities. There was a gradient in microplastic abundance, with locations more directly exposed to marine currents and tides having higher microplastic abundance and diversity, as well as a higher contribution by denser polymers (e.g. polyester). These results indicate that microplastic accumulation on shorelines in the northern Gulf of Mexico may be a serious concern, and suggest that exposure to inputs from the Gulf is an important determinant of microplastic abundance.

1. Introduction

Marine debris constitutes, "*any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or the Great Lakes*," (UNEP, 2009). Anthropogenic litter is found throughout the ocean, even in remote areas far from human contact and obvious sources of pollution (Barnes et al., 2009; Derraik, 2002). The increase in discarded trash, along with very slow degradation rates, is leading to the gradual increase of marine litter found at sea, on the ocean floor, and along the shore. In 2010 between 4.8 and 12.7 million metric tons of plastic litter reached the oceans and an estimated 5 trillion pieces of plastic are currently floating in the ocean (Cozar et al., 2014; Eriksen et al., 2014, Jambeck et al., 2015). Plastics are a diverse group of manufactured materials derived from petrochemicals, and they are lightweight, inexpensive, durable, strong, corrosion resistant, and designed to be disposable. The first plastic polymer (Bakelite) was developed in 1907 and in the 1940s, with the commercialization of plastic products, mass production increased dramatically.

One increasingly abundant type of plastic marine debris is microplastics. They come in a wide range of sizes smaller than 5 mm and have many different shapes (e.g. pellets, fragments, scrubbers; Frias et al., 2010). Microplastic debris has varying levels of buoyancy. Of the 14 different types of plastic compounds that have been found in marine environments, four can have densities lower than freshwater (expanded polystyrene, polyethylene, polypropylene, and polyester) and one has density lower than saltwater (polyamide) (Hidalgo-ruz et al., 2012; Andrady, 2011; Driedger et al., 2015). Plastic debris found in the marine environment can originate from both land and sea, with an estimated 75–90% coming from land-based activities including dumpsites, littering, tourism, fishing, and poor waste management, and 10–25% from sea-based sources, including fishing gear, shipping activities, and dumping (GESAMP, 2010; UNEP, 2005; Sheavly and Register, 2007; Andrady, 2011; Ribic et al., 2011; Mehlhart and Blepp, 2012).

Microplastics are a major environmental problem worldwide. In marine environments microplastics can be transported over long distances by ocean currents and eventually be deposited in coastal habitats such as marshes, seagrass beds, and reefs (Barnes et al., 2009). As petroleum-derived products microplastics can absorb a wide range of hydrophobic toxins including persistent organic pollutants and pharmaceuticals, thereby becoming a transportation vector for these caustic substances (Teuten et al., 2007; Browne et al., 2008, Teuten et al., 2009; Colabuono et al., 2010; Frias et al., 2010; Mato et al., 2001; Bakir et al., 2012; Browne et al., 2013, Bakir et al., 2014). Once transported into coastal habitats, microplastics interact with benthic and pelagic

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http://dx.doi.org/10.1016/j.marpolbul.2016.06.002
0025-326X/

biota, especially in shallow and well-mixed systems. Upon ingestion microplastic-borne toxins have been shown to desorb from the plastic and accumulate in various tissues and organs causing damaging effects to the organism (Browne et al., 2013; Qiu et al., 2016; Sussarellu et al., 2016).

Studies on microplastics in marine coastal systems have been carried out on both the east and west coasts of North America, the Caribbean, southern Africa, the Mediterranean, Europe, Antarctica and Asia. However, no studies have been carried out in the Gulf of Mexico. Here, we examine the abundance, distribution and composition of microplastics in Mobile Bay, a large estuarine system in the northern Gulf of Mexico. Besides contributing novel information on microplastic occurrence and composition for the Gulf of Mexico, our results provide insights on possible mechanisms that regulate the distribution and accumulation of microplastics along estuarine coastlines.

2. Methods

2.1. Study area

We sampled intertidal sandy sediments in Mobile Bay (Alabama, USA), which is located in the northern Gulf of Mexico (nGoM) and represents the fourth largest estuary in the United States, during the summer season (June–September) at low tide. Salinities within the estuary range from 0 psu (density = 1.00 g/mL) at the northern delta, where five rivers discharge freshwater, to 32 psu (density = 1.03 g/mL) at the mouth (Dauphin Island Sea Lab, 2016). The sampling locations were spread out around the estuary with four in areas primarily influenced by heavy freshwater discharge and forcing (average salinity <0.15 psu), and three in areas dominated by marine tides (average salinity >15 psu, Fig. 1).

2.2. Sample collection

Sampling was carried out along three shoreline stretches at each of the seven locations. Within each stretch, four 0.25 m × 0.25 m quadrats were randomly located along the wrack line (i.e. the line along the shoreline that represents the furthest extent of the most recent high water level) for a total of 12 samples per location. GPS coordinates were obtained for each sampled quadrat and large pieces of natural debris (i.e. seaweed, leaves, wood) was brushed off and removed. Subsequently the top layer of sediment (approximately 3–6 cm) was removed and sieved through a 5 mm sieve into a collection container, items (including plastic) larger than 5 mm were discarded. The collected material (~14 L from each section) was then transported to the lab for processing.

2.3. Microplastic separation

Separation of microplastics from other collected matter was accomplished using a combination of sieving (items between 0.5 and 5 mm), density separation (items between 200 and 500 μm), and visual sorting. Our technique includes novel features that facilitate microplastic isolation. Using a combination of hand sieving and mechanical Ro-tap, all samples were passed through a series of mesh sizes (5 mm, 4 mm, 2 mm, 1 mm, 0.5 mm) and the retained material inspected visually for microplastics. The material that passed through all sieves (<0.5 mm) was retained for density separation.

To carry out the separation of microplastic particles <0.5 mm, we designed a separation process that uses density differences to mechanically separate sand and plastic particles (Fig. 2). The separator was constructed with a series of PVC pipes and connectors. A disk, made from flat stock PVC was secured in between the standard schedule 40 PVC and the bottom tee, served as a barrier between the water reservoir and the sample material. The disk had twenty five, 1-cm holes drilled randomly throughout and 1 mm and 50 μm mesh layers glued to it. The threaded male adaptor on the bottom tee was attached to an ECODIVER 1000 submersible pump that supplied recirculating >35 psu filtered water.

Approximately 3 L of sample material was added at a time through the top tee onto the disk, and the >35 psu water was pumped into the separator through the bottom tee. The flow was adjusted with the ball valve until fluidized sandy sediment was approximately 30 cm from the top of the density separator. Microplastic particles, less dense than sand and the >35 psu water, were carried by the flowing water to the top of the separator. Both microplastic particles and the >35 water exited the separator through the top tee and, after passing through a 200 μm capture sieve, the water was recirculated into the separator. Aeration was provided with a Sweetwater Linear II model SL24 aerator, applied with a 1/4 in clear flexible tubing and airstone that was placed through the top of the separator to approximately 10 cm above the disk. Pneumatic flow was controlled to minimize the amount of sediment material exiting the separator, while still facilitating the upwelling of less dense particles. Each sample was processed for 26 min (the minimum time necessary to capture the most microplastics possible), at

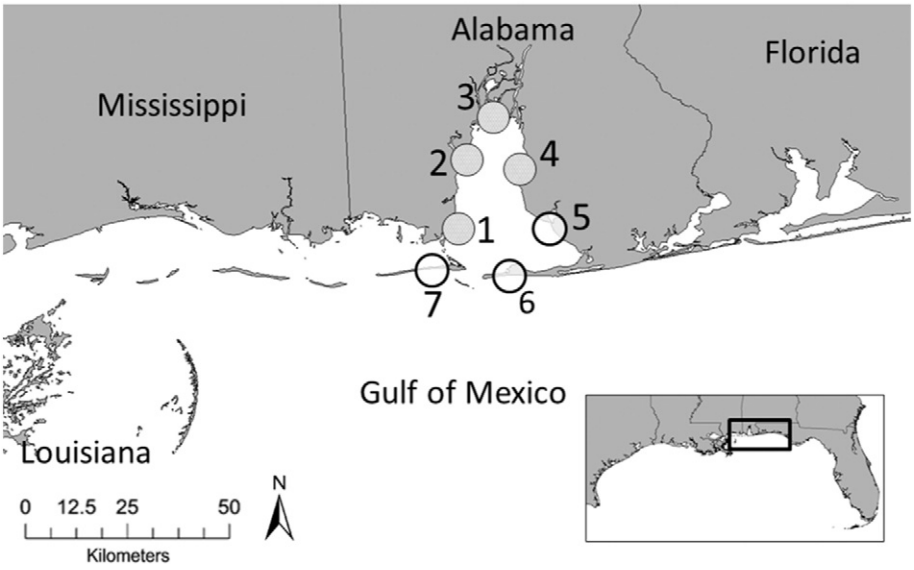

Fig. 1. Study locations around Mobile Bay, AL. Gray dots represent the four areas primarily influenced by riverine outflow and the white dots represent the three in areas heavily influenced by marine tides.