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Microplastic pollution of the beaches of Guanabara Bay, Southeast Brazil

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ABSTRACT

Plastic debris is widely recognized as an important marine environmental pollutant. Plastics pollution of coastal areas is a growing concern, with research efforts focusing on macroplastic (>5 mm) and microplastic fractions. Currently, a large proportion of the plastics found in the ocean are in the form of microplastics (<5 mm). Due to their buoyant and persistent properties, microplastics have the potential to be widely dispersed via hydrodynamic processes and ocean currents. Guanabara Bay has been identified as one of the most polluted environments on the Brazilian coastline, mainly due to the presence of heavy metals and hydrocarbons. The aim of this work was to investigate, using field surveys, the abundance, composition and distribution of microplastics and small plastic fragments on the beaches of Guanabara Bay, located in southeastern Brazil. Microplastic concentrations ranged from 12 to 1300 particles per m^2on the beaches. Fibres, fragments, styrofoam and pellets accounted for 8766 particles, with microplastic fragments representing 56% of the total detected debris, followed by styrofoam fragments (26.7%), pellets (9.9%) and fibres (7.2%).

1. Introduction

Estuaries are highly productive but also highly vulnerable areas, and many estuaries have changed greatly in the last 150 years due to increased pollution resulting from rapid urbanization and the growth of industrial activities (Rebello et al., 1986; Kjerfve et al., 1997; Baptista Neto et al., 2006; Covelli et al., 2012; Vilela et al., 2014). In the last 100 years, the catchment area around Guanabara Bay, one of the most prominent coastal bays in southeastern Brazil, has been strongly modified by human activities; Guanabara Bay is surrounded by the second most important metropolitan area in Brazil (Amador, 2012). In recent decades, land disturbance and urbanization have significantly increased sediment input to and pollution of the bay, negatively affecting its overall environmental health (Baptista Neto et al., 2013). Guanabara Bay is recognized as one of the most polluted ecosystems in Brazil (Rebello et al., 1986; Barrocas and Wasserman, 1993; Kjerfve et al., 1997; Baptista Neto et al., 2006; Carreira et al., 2002; Covelli et al., 2012; Vilela et al., 2014). However, studies of marine debris remain sparse not only in the Guanabara Bay area but in all of the coastal areas of Brazil (Ivar do Sul et al., 2013).

Marine debris is recognized as one of the most important and common environmental pollutants. It is a global issue and causes multiple ecological impacts (e.g., Gregory, 2009; Rochman et al., 2013a,b; Vegtner et al., 2014). Anthropogenic debris accumulates in marine ecosystems throughout the world, from coastal waters to deep seas. The majority of the anthropogenic debris found in the seas is composed of plastic material (60–80%) (Derraik, 2002; Vegtner et al., 2014). Plastics are a ubiquitous part of modern life, encountered on a daily basis in the packaging of foods and drinks, in household items such as combs, toothbrushes and pens, and in shopping bags. Since mass production of plastics began in the 1940s, worldwide plastic production has dramatically risen to approximately 280 million tonnes, as of 2011 (PlasticsEurope, 2012). Global consumption of plastics is expected to grow by approximately 4% each year up to 2016 (PlasticsEurope, 2012).

Plastic is popular because of its lightweight, durable nature and low price, but its longevity presents a challenge when disposed of improperly, resulting in long-term accumulation in the environment. The final destination of many large plastic items is the ocean, where they form macroplastic debris (>5 mm, Moore, 2008) that is a dominant component of ocean pollution, threatening marine life through consumption and/or entanglement (Derraik, 2002; Moore,

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2008; Vegtner et al., 2014). Microplastic debris enters the marine environment from sea-based sources, such as vessel-traffic and fisheries, or from land-based sources, such as coastal tourism, river run-off or industry (Andrady, 2011).

The occurrences, quantities, types and environmental consequences of macroplastics in coastal areas and oceans have been well studied since the early 1970s (Carpenter and Smith, 1972; Colton et al., 1974). Many forms of plastic have been accumulating in global environments for decades (Barnes et al., 2009), and may continue to increase in concentration in marine environments (Thompson et al., 2004), where the adverse effects of this type of pollution on marine life have been described extensively (e.g., Carr, 1987; Laist, 1987, 1997; Browne et al., 2008; Graham and Thompson, 2009; Vegtner et al., 2014).

Recent studies suggest that microplastics present greater hazards to marine organisms than larger-sized plastic materials, as organisms occupying the lower trophic levels, such as plankton, are particularly susceptible to microplastic ingestion, with consequent effects on organisms at higher trophic levels via bioaccumulation (Eriksson and Burton, 2003; Thompson et al., 2004; Ivar do Sul et al., 2013). Microplastics are <5 mm, as classified bythe National Oceanic and Atmospheric Administration (NOAA), and they occur in a heterogeneous array of shapes and sizes (Betts, 2008; Hidalgo-Ruz et al., 2012; Wright et al., 2013). The most important microplastic forms observed in the marine environment are spheres, pellets, irregular fragments, and fibres (Wright et al., 2013).

The aim of this study was to investigate the occurrence and distribution of microplastics in Guanabara Bay (Brazil) coastal sediments (Fig. 1). Samples were collected from different sandy beaches in the entrance and in the inner part of the bay. The extracted microplastics were counted and grouped according to quantity and distribution. Our major objective was to identify differences in the distribution pattern and concentration of microplastics between the inner beaches and the bay entrance.

2. Methodology

2.1. Study area

Guanabara Bay is located in Rio de Janeiro State, Southeast Brazil (Fig. 1), between 22°40′S and 23°00′S latitude and between 043°00′W and 043°18′W longitude. It is one of the largest bays on the Brazilian coastline and has an area of approximately 384 km^2, including islands. Guanabara Bay has been identified as one of the main polluted environments on the Brazilian coastline (Rebello et al., 1986; Barrocas and Wasserman, 1993; Kjerfve et al., 1997; Baptista Neto et al., 2006; Carreira et al., 2002; Amador, 2012; Covelli et al., 2012; Vilela et al., 2014). In the last 100 years, the catchment area around Guanabara Bay has been strongly modified by human activities; in particular, deforestation and uncontrolled settlement have increased marine contamination from sewage effluent, industrial discharge, urban and agricultural runoff, atmospheric fallout, and the combined input from the rivers that enter the bay (Baptista Neto and da Fonseca, 2011; Amador, 2012).

According to Amador (2012), the coastline of the bay is 131 km long and the mean water volume is 1.87×10^9 m^3. The bay measures 28 km from west to east and 30 km from south to north, but the narrow entrance to Guanabara Bay is only 1.6 km wide (Kjerfve et al., 1997). This narrow entrance influences hydrodynamics in the bay, increasing current velocity and creating greater dynamism, which can contribute to the export of pollutants into the adjacent coastal environment (Melo et al., 2015). Guanabara Bay has a complex bathymetry with a relatively flat central channel. The channel is 400 m wide and stretches from the mouth more than 5 km into the bay and is defined by the 30 m isobath. The deepest point of the bay measures 58 m and is located within this channel (Kjerfve et al., 1997; Melo et al., 2015). The channel loses these characteristics north of the Rio de Janeiro-Niterói Bridge as the bay rapidly becomes shallower, with an average depth of 5.7 m (Kjerfve et al., 1997; Melo et al., 2015). This change in depth is due to the high rates of sedimentation that have accelerated in the past century, due to anthropogenic activities in the catchment area.

Guanabara Bay lies within the tropics of southeastern Brazil, but because of its coastal location, a humid sub-tropical climate with 2500 mm of rainfall (at high altitudes) and 1500 mm of rainfall (at low altitudes) occurs between December and April. The mean annual temperature is between 20 and 25 °C (Nimer, 1989). The bay receives untreated agricultural runoff and urban and industrial sewage from rivers, from the Rio de Janeiro metropolitan area, from two harbours, from refineries, and from more than 12,000 industries in the drainage basin which account for 25% of the organic pollution released to the bay (FEEMA, 1990; Kjerfve et al., 1997; Baptista Neto et al., 2006).

The drainage basin of Guanabara Bay has an area of 4080 km^2, consisting of 32 separate sub-watersheds with 91 rivers and channels (Kjerfve et al., 1997). However, only six rivers are responsible for 85% of the total mean fresh water input, on the order of 100 $m^3\ s^{-1}$ (JICA, 1994). These main rivers are: Guapimirim (20.8%), Iguaçu (16.7%), Caceribu (13.7%), Estrela (12.7%), Meriti (12.3%) and Sarapui (9.3%) (Kjerfve et al., 1997; Baptista Neto et al., 2006).

2.2. Field work

Data collection was divided in two surveys, one carried out during the summer (January–February) and the second during the winter (June–July), to characterize the two main seasons experienced in this area. Field surveys were carried out at 17 sandy beaches in Guanabara Bay, although some of the beaches were not surveyed during the summer. At each beach, samples were collected at two sites, for a total of 35 sites visited during the summer and winter of 2015 (Fig. 1). Beach was chosen to represent different exposures to wind and currents, uses, proximity to river mouths, or location relative to the entrance or the inner part of the bay. Sampling occurred on the sandy portion of all of the beaches; the rocky shorelines were avoided as they normally contained man made features and mangrove areas were avoided because muddy coastal sampling requires different methodology.

Samples were collected at the high tide line. The “highest high tide” or “spring tide” was avoided, and we also excluded the abnormal concentrations of multi-generational accumulation lines. At each beach, 1.0 m by 1.0 m quadrats were placed and sand was collected to a depth of 5 cm to sample microplastics that were deposited by the most recent tide, which are found in the uppermost section of the sedimentary cover. At each beach, two sediment samples were collected and stored in new 10 L plastic buckets until analysis. For each sample, 7 L of saline solution (NaCl) was added to the bucket and stirred for three to four minutes, with periods of rest in between. The supernatant was then collected and filtered using filter paper (47 mm) and oven dried at 60 °C. Samples were stored in petri dishes until analysis. The microplastic was separated from the organic particles and then identified visually under a stereomicroscope, to determine size classes. These size classes were then sorted into categories according to their appearance, characteristics and possible origin (such as from fishing activities, fibres, fragments, styrofoam or preproduction pellets).

3. Results and discussion

Microplastics were found in different concentrations at all