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On the importance of size of plastic fragments and pellets on the strandline: a snapshot of a Brazilian beach

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Abstract Virgin plastic pellets and plastic fragments are reported as ubiquitous beach contaminants in the peer-reviewed literature. A surface density of 0.3 virgin plastic pellets and plastic fragments per square centimeter of the strandline area was registered on an urban beach of the northeast of Brazil. This beach is presently not affected by petrochemical facilities or pellet processing plants. The main source of fragments (96.7%) was attributed to the breaking down of larger plastic items deposited on the beach. In the case of virgin plastic pellets (3.3%), the main sources were the marine environment and possibly nearby port facilities. This category of plastic pollutant offers particular threats to the marine environment and to beach users.

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Introduction

The occurrence of plastic debris in different coastal and marine environments is well documented (Coe and Rogers 1997; Ivar do Sul and Costa 2007; Moore 2008; UNEP 2009). Virgin plastic pellets and plastic fragments are frequently found either floating on the sea surface, deposited on the bottom, or on sandy beaches. These are the virgin plastic material from which larger molded plastic items are made (Wilber 1987) and usually occur in the form of small rounded shapes (2 to 5 mm). In addition, plastic items of all types eventually undergo some form of degradation and subsequent fragmentation (Ng and Obbard 2006) leading to the formation of small fragments that have suffered thermal, photochemical (sun), chemical (salting and burial in sand rich in organic matter), or physical (wind, waves, and sand abrasion) degradation. Despite their distinct sources, at some stage in the fragmentation process, virgin plastic pellets and plastic fragments become similar in size and behave similarly in the environment.

Although fragments and plastic pellets are usually classified according to size, there is as yet no

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consensus nomenclature for describing size. Here, based on the existing literature (Table 1), it is proposed that the virgin plastic pellets and plastic fragments larger than 1 mm but less than 20 mm are termed *small*, whereas items that continue to break down into even smaller pieces (Santos et al. 2009) are specifically called *microplastics* (1 mm or less). Thus, *small* plastics are those fragments and pellets which cannot be easily sampled by hand on the beach (or sea surface), but can be identified and counted in the laboratory without optical instruments (i.e., stereomicroscope), whereas *microplastics* refer to those which cannot be collected individually on beaches (or sea surface) and can only be identified and analyzed in the laboratory (for example, Thompson et al. 2004).

These size fractions are not normally distinguished in the majority of reports dealing with marine debris, probably due to sampling difficulties associated with large scale surveys involving hundreds of square meter transects (Ivar do Sul and Costa 2007; Moore 2008; UNEP 2009). Therefore, their sources, fate, and further environmental consequences are poorly understood (Sheavly and Register 2007).

Nevertheless, threats to marine biota from virgin plastic pellets, small fragments, and microplastics have been reported in the scientific literature. The ingestion of these size fractions affects a large number and diversity of species, when compared, for example, to the entanglement of vertebrates. Ingestion of small plastic items has been reported in marine birds—which seem to be the most heavily affected group (Blight and Burger 1997; Mallory 2008)—mammals (Erikson and Burton 2003), turtles (Balazs 1985), fishes and squids (Laist 1997), and even marine invertebrates (Thompson et al. 2004; Browne et al. 2008). In Brazil, virgin plastic pellets and small plastic fragments have also been reported, both on sandy beaches and in the stomach contents of marine animals (Ivar do Sul and Costa 2007). In spite of these and other reports, the most harmful effects of small fragments and microplastics remain largely speculative (Ng and Obbard 2006).

Other unpredicted consequences of improper use and disposal of plastics on beaches and in the marine environment as a whole have also been reported (Donohue and Foley 2007). For microplastics specifically (<1 mm), registers have been made of the use of cosmetic products (peeling creams and soaps, tooth paste, etc.), which could end up in the ocean via sewage systems (Zitko and Hanlon 1991; Gregory 1996; Fendall and Sewell 2009). Plastic items thrown into the ocean can transport alien organisms (Barnes 2002), hurt people (Santos et al. 2005), entangle marine animals (Laist 1997), associate with persistant organic

Table 1 Size categories (millimeters) and marine habitats considered in pollution studies referring to virgin plastic pellets, small plastic fragments, and microplastics

Size (mm)	Habitat	Nomenclature	Reference
4 to 6	Beaches in New Zealand	Pellets only	Gregory 1977
1 to 5	Beaches in Canada and Bermuda	Pellets only	Gregory 1983
2 to 5	Western North Atlantic Ocean	Pellets only	Wilber 1987
0.1 to 0.2	Laboratory	Spherules only	Zitko and Hanlon 1991
<0.5	Laboratory	Micro	Gregory 1996
2 to 5	Faeces of fur seals in Macquarie Island	Small	Erikson and Burton 2003
1 to 15	Beaches in Hawaii	Small	McDermid and McMullen 2004
~2	Beaches, coastal sediments, and invertebrates in UK	Micro	Thompson et al. 2004
>0.16	Beaches and coastal waters in Singapore	Micro	Ng and Obbard 2006
2 to 20	Beaches, Fernando de Noronha	Small	Ivar do Sul et al. 2009
20 to 100	Archipelago, Equatorial Atlantic	Medium	
2 to 5		Plastic pellets	
0.01 to 0.5	Laboratory	Micro	Fendall and Sewell 2009
1 to 20	Boa Viagem beach in Brazil	Small	Present work
<1		Micro	

Only widely available sources which referred to a defined size nomenclature are listed small plastic fragments, and microplastics

pollutants (Mato et al. 2001; Teuten et al. 2004), and even be ingested (Thompson et al. 2004; Browne et al. 2008) by almost every filter feeder or small predator in the water column and benthos.

Considering that plastic pollution of coastal and marine environments is ubiquitous (Coe and Rogers 1997; Ivar do Sul and Costa 2007; UNEP 2009), it is possible that small plastic fragments and microplastics are also widespread and prevalent in every coastal and marine environment (Ivar do Sul et al. 2009). The sources of virgin plastic pellets are usually plastic pellet processing facilities, e.g., injection molding, blow molding, bag, and sheet making; port facilities, e.g., container terminals; petrochemical plants; and other specific trading activities such as oceanic shipping routes, but they can be carried to almost every habitat by oceanic currents and winds. Some habitats, such as convergence zones (Moore et al. 2001; Moore 2008) and the strandline of dissipative beaches, will probably have a more significant accumulation of these size fractions of plastic pollution due to their natural characteristics. Therefore, marine biota using these environments will be at a greater than average risk of plastic ingestion. This is an important concern since these habitats are gathering places for plankton and other organic matter and therefore feeding grounds for many marine species. The objectives of the present work were to detect the presence of virgin plastic pellets on an urban beach on the northeast of Brazil and to assess their prevalence in relation to small plastic fragments and microplastics sampled opportunistically.

Boa Viagem beach, at Recife (Fig. 1), is a dissipative sandy beach and, as previously reported, contaminated by plastics, especially the strandline (Silva et al. 2008; Silva-Cavalcanti et al. 2009). This beach is under the influence of Recife and Suape ports (5 km north and 30 km south, respectively; Fig. 1). Until now, it has been free from the influence of petrochemical facilities though this will soon change as a petrochemical complex is being installed south of the studied site (Suape hub-port). The industrial park around the Recife Metropolitan Area is relatively small and few pellet processing plants are present due to the lack of a supplier. Most food containers, for instance,

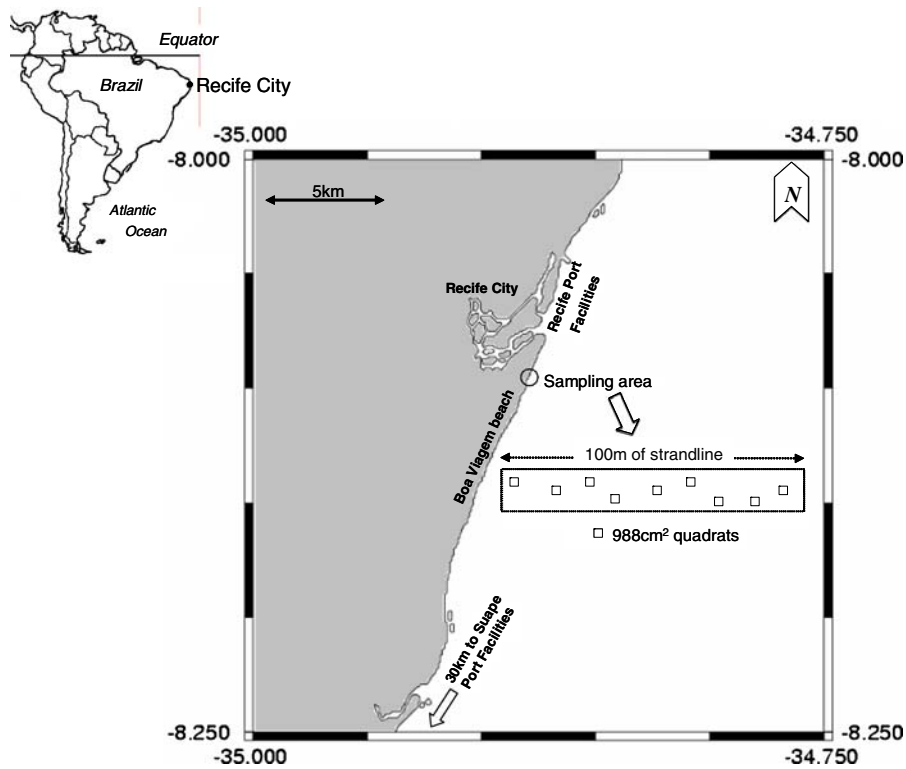

Fig. 1 Boa Viagem beach, Recife, northeast Brazil and the sampling strategy of the nine 988-cm^2 quadrats along 100 m of the strandine

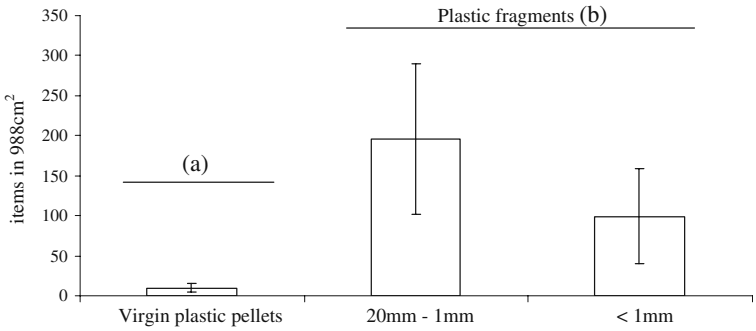

Fig. 2 Mean and standard deviation of number of plastic items (virgin plastic pellets and plastic fragments). Kruskall–Wallis test results are divided into two significantly different groups *a* and *b*

are imported since the state of Pernambuco still relies principally on sugarcane plantations, cattle, irrigated fruticulture, and tourism for its revenues. This report will therefore serve as a baseline for future assessment of changing plastic contamination patterns.

Material and methods

The strandline (1 m wide) of Boa Viagem beach was sampled for virgin plastic pellets and small fragments and microplastics by scraping the first 2 cm of sand from nine 988-cm^2 quadrats along a 100-m transect (Fig. 1). Samples were oven-dried at 100°C overnight and sieved through 1- and 0.5-mm wire cloths. The retained material was examined and the organic and nonplastic items were discarded. The remaining plastic items were classified as small (<20 mm) and microplastics (<1 mm), which were analyzed under stereomicroscope. The plastic fractions retained by each sieve were washed in filtered seawater to clean the floatable virgin plastic pellets and plastic fragments from the remaining sand, dried, weighed, and counted. The colors and other characteristics of the pellets were recorded. The nonparametric Kruskall–Wallis statistical test was used to analyze the total number of plastic fragments (small and microplastics) and virgin plastic pellets sampled.

Results and discussion

The primary objective of the present work was to detect the presence of virgin plastic pellets on an urban beach free from the influence of petrochemical facilities and significant pellets processors, but where plastic debris contamination was evident. The occurrence of virgin plastic pellets was confirmed. A total of 90 were sampled, varying from four to 20 in each single quadrat (10 ± 5.5; $N = 9$) with a surface density of 0.01 pellets per square centimeter. They were not only white or pearly but also bluish/greenish and brownish, similar to the pattern observed worldwide (EPA 1992). Some were cylindrical, others oval-shaped, and others still were squashed.

The presence of these virgin plastic pellets implies long-range marine transport since there were no local sources close to the study site. Virgin plastic pellets accounted for only 3.3% of the 2,751 sampled plastic items that were distributed at a much higher surface density. Therefore, virgin plastic pellets were significantly rare ($p < 0.05$, Kruskall–Wallis) among the plastic fragments as a whole (Fig. 2). These results show that at present, the beach is significantly more contaminated by small fragments and microplastics than by virgin plastic pellets.

A total of 2,661 plastic fragments were sampled, varying from two to 231 in each single quadrat (76 ± 63.4; $N = 9$) and with an overall density of 0.29 items per square centimeter. They were mainly white and pearly, but many other colors such as red, green, blue, yellow, and pink also occurred. Fragments had all sorts of shapes, but the majority were jagged fragments of hard plastic. These fragments varied widely in terms of weathering, ranging from new to those showing obvious signs of exposure to the tropical/marine environment conditions.

No conclusions about the prevalence of small plastic fragments (20–1 mm) in relation to microplastics (<1 mm) could be made. The small ones were apparently the majority (64.2%) in the samples studied. However, it was not possible, at this stage, to estimate the <0.5 mm fraction.

Small plastic fragments comprise a frequently reported size category in ingestion studies (Erikson and Burton 2003; Thompson et al. 2004). For this reason, they must be regarded as a real threat to marine life and maybe even to unsupervised children since the shape and colors might resemble edible items. Colored fragments and virgin plastic pellets, especially those resembling natural organic matter, e.g., *Sargassum* floats, are prone to ingestion by birds (Blight and Burger 1997) and other animals. Potential mouth contact and/or ingestion of other items such as cigarette filters by children playing on the beach have also been raised as a public health concern.

The microplastic size category principally threatens filter feeders which live on or in the sand and other soft underwater substrata. In the case of Boa Viagem beach, where beach rocks are present along half of the length, there is additional risk to the sand macrofauna (e.g., ghost crabs and other infaunal crustaceans). Sand contaminated with microplastics may accumulate in the reef's microhabitats exposing its inhabitants to plastic pollution and even becoming incorporated in the beach rock itself. In the case of plastic fragments, pollution by large plastic items from beach users and rivers will become increasingly difficult to mitigate against since the development of the problem occurs after the items have reached the marine environment and consequently is beyond control.

Final considerations

The present results reinforce the idea that at any place and time, if a beach is sampled for small- and micro-sized categories of plastics, including virgin plastic pellets, it will almost certainly be found to be contaminated (Ivar do Sul et al. 2009). As there are no cleaning services available for these items (Santos et al. 2005; Araújo and Costa 2006), the only option is to prevent spillage of virgin plastic pellets at their sources and always try to abate and combat the presence of larger plastic items in the environment.

The ubiquitous prevalence of virgin plastic pellets and fragments within the marine environment urgently calls for the development and standardization of new methods, larger scale surveys, and periodical samplings for the establishment of patterns and behaviors of these poorly understood categories of plastics in marine and coastal environments. The establishment of a consensual nomenclature associated with different size categories is fundamental to the development of plastic marine debris research.

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