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Characterization of small plastic debris on tourism beaches around the South China Sea

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HIGHLIGHTS

- Small-plastic debris (1–20 mm) contamination levels are investigated for the first time in China.
- Small plastics accounted for more than 60% of the total plastic by number.
- An exponential damping relation was statistically significant between the size and amount of plastic particles.
- Polypropylene and polyethylene were the most common polymer composition.
- This study provides baseline information of small plastic debris pollution for effective and comprehensive management actions in coastal China.

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ABSTRACT

Small plastic debris (1–20 mm) pollution levels are investigated for the first time in China. Small plastics from six tourism beaches around the South China Sea, which were divided into two groups to examine the influence of riverine inputs, were quantified and sorted into several categories. Representative plastics were identified using Raman spectroscopy. Vast amounts of plastic remain in beaches after beach cleaning. Spatial discrepancies in the amounts of plastics were observed, with the greatest quantity observed at Zhuhai and Weizhou Island. Small plastics accounted for 63.4% of plastic debris quantified by number. Larger plastics (> 20 mm) made up 74.7% of the total plastic weight. An exponential damping relationship between the size and amount of plastic debris was determined, although it is only of borderline significance ($\alpha = 0.05$). Plastic shapes were heterogeneous among the beaches. Polypropylene (59.7%) and polyethylene (31.9%) were the most common polymer compositions in the selected samples. Coloured and white plastics were more prevalent than black and transparent ones. This study provides baseline information of small plastic debris pollution for effective and comprehensive management actions.

1. Introduction

Sandy beach pollution with plastic debris has been documented extensively (Derraik, 2002; Leite et al., 2014). Plastic debris on beaches consists of plastic fragments, pellets, films, discarded fishing gear, scrubbers and flakes (Corcoran et al., 2009; de Araujo and da Costa, 2007). Originating from inland sources or from ocean-based sources, plastic litter has a relatively high abundance and accumulation along coasts globally (do Sul et al., 2011; Rech et al., 2014; Santos et al., 2009).

Beach clean-ups, which generally focus on larger particles along strandlines at tourism beaches (Ryan and Swanepoel, 1996), are direct and effective mitigation measures. The selective removal of large items from beaches before they are weathered enough to develop surface embrittlement can greatly decrease microplastic loads (Barnes et al., 2009). However, small plastics, which are not easily collected by hand on beaches, can nonetheless be identified and enumerated only via naked eye inspection in the laboratory (Moore, 2008; Santos et al., 2009) and are often ignored by cleaning teams, resulting in their continued deposition on beaches worldwide (Leite et al., 2014). In addition, these plastics are ingested by the marine biota (do Sul et al., 2011; Wright et al., 2013), altering the physical properties of the beaches (Carson et al., 2011). Small plastics also fragment into even smaller particles termed microplastic (< 1 mm), which have a longer residence time and cause greater harm to the environment (Andrady, 2011). The beach setting has been considered the most suitable environment on earth for plastic degradation (Cooper and Corcoran, 2010).

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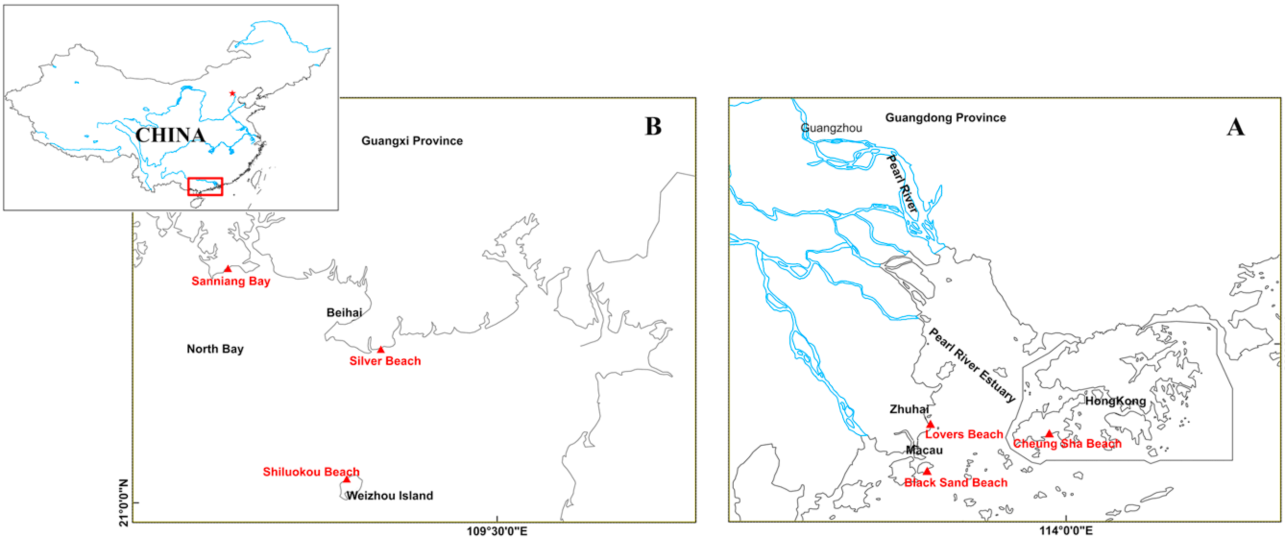

Fig. 1. The location of tourism beaches quantified for plastic debris in the study (A: beaches with the Pearl River inputs; B: beaches without riverine inputs; Red triangles: sampling sites). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Microplastics, which can physically and chemically harm wildlife via ingestion, have dispersed globally in oceans and posed a long-term threat to the marine ecosystem (Andrady, 2011). Thus, it is imperative to elucidate the origins, concentration and environmental consequences of small plastic debris.

China together with the USA and Europe are the biggest producers of plastic litter (Rochman et al., 2013). Beaches around the South China Sea are used frequently for multiple recreational purposes. Additionally, the coastline along the South China Sea is densely populated. However, no previous studies have specifically examined small plastic waste in China. Here, we collected plastic samples from six tourism beaches in South China (Fig. 1) to determine the abundance and distribution of small plastics. This study was conducted during April to May, 2014 and assessed small plastic debris on selected tourism beaches in South China for the first time. In addition, the selected plastics were characterized with respect to their common polymer composition using a Raman spectrometer. This study provides baseline information to estimate the magnitude of the problem posed by small plastic debris pollution.

2. Materials and methods

2.1. Sample collection

Beach surveys were conducted at six coastal tourism beaches from April 24 to May 3, 2014 (Fig. 1). Beaches located at Zhuhai, Macau and HongKong were potentially affected by riverine inputs, while beaches located at Qinzhou, Beihai and Weizhou Island lacked the impacts of large rivers (Table A.1). At each site, sampling was conducted following the final clean-up operation on the same day. A 100-m lateral high-tide line located in the core area of the tourism beaches studied was determined to conduct the sampling. Sand with plastic debris was collected by scraping the first 5 cm of sand from four 50 × 50 cm^2 quadrats at intervals of twenty-five metres (Galgani et al., 2011; Jayasiri et al., 2013). Samples were placed in labelled bags and transferred to the laboratory.

2.2. Analysis

In the laboratory, each sample was floated on sodium polytungstate solution (1.4 g/mL, Corcoran et al., 2009). Visible floating plastics were removed from the water surface, ultrasonically cleaned, oven-dried at 40 °C, counted and weighed to the nearest 0.001 g. The identified plastics were measured at their largest cross-section using a pair of callipers and classified into four groups: micro (≤5 mm), meso (>5–20 mm), macro (>20–100 mm) and mega (>100 mm) (do Sul et al., 2011; Jayasiri et al., 2013). The plastic debris was also categorized according to shape (i.e., fibre, film, granule or pellet) and colour (i.e., white, black, coloured or transparent).

Based on visual examination of four different plastic shapes, a representative group of plastic debris from each sample was randomly selected for polymeric matrix identification using micro-Raman spectroscopy (LabRam-1B, Dior). The polymer composition of the samples were compared with the Raman spectra of specific polymer references (Kuptsov, 1998) and identified. The sandy grain size was calculated using a Beckman Coulter LS 13 320 (laser diffraction particle size analyser).

2.3. Statistical analysis

The data sets were examined and transformed when necessary. Logarithmic Transformation were used only for Kolmogorov–Smirnov test and Levene's test of equality of variances of the data. The results showed that they were not normally distributed (Kolmogorov–Smirnov test) and that their variances were not homogeneous (Levene's test). There is a dependency of the variance on the mean as well. Hence, the nonparametric Kruskal–Wallis statistical test was used to analyse multiple comparisons. If the test indicated significant differences, pair-wise comparisons were performed using the nonparametric Mann–Whitney U-test (significance level, 0.05). The relationship between mean plastic size and abundance by number was examined via linear and nonlinear regression.

3. Results

3.1. Abundance of plastic debris

Twenty-four quadrants were sampled at six tourism beaches around the South China Sea. Some examples of plastic debris collected during the study are shown in Fig. 2. A total number of 587.0 items (42.3 g) was collected, with a mean density of 97.5 ± 157.4 n/m^2 (0–636 n/m^2) and 7.0 ± 12.1 g/m^2 (0–44.4 g/m^2) (Table A.2). Discrepancies in average plastic abundance based on