Science of the Total Environment 562 (2016) 658–665

Contents lists available at ScienceDirect

Science of the Total Environment

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

Seasonal variation in the abundance of marine plastic debris in the estuary of a subtropical macro-scale drainage basin in South China

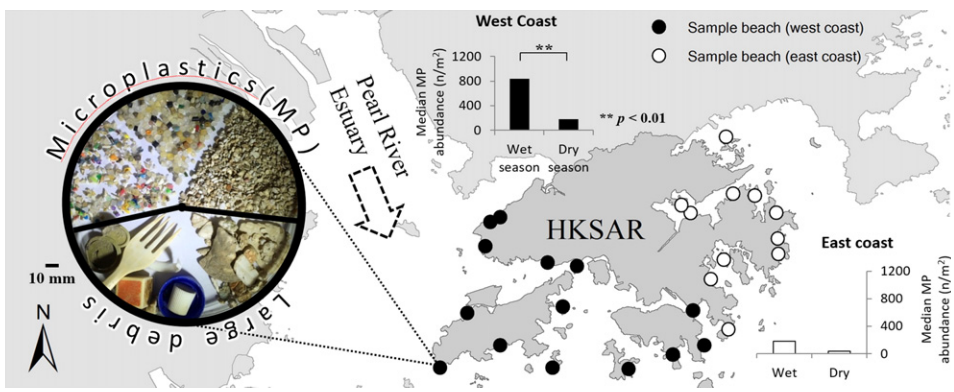
Pui Kwan Cheung [a], Lewis Ting On Cheung [b], Lincoln Fok [a,*]

[a] Department of Science and Environmental Studies, The Hong Kong Institute of Education, 10 Lo Ping Road, Tai Po, Hong Kong, China
[b] Department of Social Sciences, The Hong Kong Institute of Education, 10 Lo Ping Road, Tai Po, Hong Kong, China

HIGHLIGHTS

- The seasonal variation in the abundance of marine plastic debris was investigated in a subtropical estuary.
- Plastic debris was sampled at 25 beaches during the wet and dry seasons.
- Significant seasonal variations in both large debris and microplastics were detected.
- The results suggest that marine debris in estuaries is largely controlled by fluvial inputs.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 15 February 2016
Received in revised form 6 April 2016
Accepted 8 April 2016
Available online xxxx

Editor: J Jay Gan

Keywords:
Microplastics
Marine plastic debris
Seasonal variation
Beach survey
Hong Kong
Pearl River

ABSTRACT

Marine plastic debris, including microplastic debris (0.315–5 mm) and large plastic debris (>5 mm), was collected from 25 beaches in Hong Kong during a wet summer season (June–August 2014) and the following dry winter season (January–March 2015). Wilcoxon signed rank tests were used to compare the abundances and weights of seven categories of plastic debris between the two seasons. The results showed that the abundances and weights were significantly higher ($p < 0.05$) in the wet season than in the dry season. Additionally, seasonal differences were detected only at the sites that were located on the west coast of Hong Kong and not at the sites on the east coast. These results suggest that the Pearl River Estuary on the west of Hong Kong plays a prominent role in the abundance and distribution of plastic debris in Hong Kong. In addition, the study indicates that estimates of microplastic abundance may be biased if samples are collected only during the wet or dry season if the sample locations are strongly influenced by a seasonal variation of riverine inputs, such as from the Pearl River.

1. Introduction

Marine plastic debris is a subject of growing concern because of its persistence in the environment (Andrady, 2015) and its negative impacts on marine organisms (Gregory, 2009). Among plastic debris, ‘microplastics’ are of particular concern because of their small particle

* Corresponding author.
E-mail address: lfok@ied.edu.hk (L. Fok).

http://dx.doi.org/10.1016/j.scitotenv.2016.04.048
0048-9697/

size and ubiquitous nature (Thompson et al., 2004). Microplastics are often described as anthropogenic plastic debris that has a particle diameter of <5 mm (Arthur et al., 2009). Previous studies have reported extensive microplastics contamination in various environments, such as the ocean surface (Cozar et al., 2014; Song et al., 2015), beaches (Fok and Cheung, 2015; Frias et al., 2016), rivers (Lima et al., 2014; Mani et al., 2015) and even the deep ocean (Van Cauwenberghe et al., 2013). Concerns related to the potential ingestion of microplastics by organisms that live in these environments have increased because ingested microplastics can accumulate in the organisms' digestive systems and lead to internal blockages (Carpenter et al., 1972) and reduced energy reserves (Wright et al., 2013). In addition, microplastics are known to sorb toxic chemicals at rates up to one million times higher than that of ambient seawater (Mato et al., 2001), and several of these chemicals can eventually be transferred to the biological tissue of the host organisms through ingestion (Teuten et al., 2009).

Numerous research projects investigated the abundance and geographic distribution of anthropogenic plastic debris in beach and marine environments (Zhou et al., 2011; Hidalgo-Ruz and Thiel, 2013; Vianello et al., 2013). Other studies have explored the factors that affect the deposition and accumulation of plastic debris, and wind and rainfall have been observed to exert prominent influences on the preferential accumulation of debris in certain locations (Moore et al., 2002; Browne et al., 2010). However, studies on the temporal or seasonal variations in the abundance and distribution of plastic debris, particularly microplastics, are relatively scarce (Thompson, 2015). Several seasonal studies have demonstrated positive relationships between rainfall and the abundance of plastic debris on beaches (Shimizu et al., 2008; Ivar do Sul and Costa, 2013) and in estuaries (Lima et al., 2014). Anthropogenic debris is believed to be transported by surface runoff into streams, rivers, stormwater drainage systems and finally to coastal waters and beaches during wet seasons (Araújo and Costa, 2007; Lima et al., 2014). For example, microplastics on the sea surface near the southern Californian coast were found to be seven times more abundant after a 90-mm rainfall event, which reflects the contribution of surface runoff to the increase in land-based inputs of debris through drainage systems (Moore et al., 2002). Drainage systems, such as river systems, may therefore be an important vector for the transport of land-based plastic debris into marine environments. The study of Chilean rivers by Rech et al. (2014) confirmed that fluvial systems are a prominent source of marine debris because they observed similar compositions between the anthropogenic debris that was sampled from the upper course of the river and the debris from the coastal beaches near the estuarine areas. Thus, in regions with distinct seasonal precipitation patterns, variations in land-based inputs over time must be considered when determining the representative abundance and geographic distribution of microplastics on a regional scale. However, this environmental factor has yet to be investigated.

The Hong Kong Special Administrative Region (HKSAR) is located in the Pearl River Estuary, which drains several populous cities in Guangdong Province, including Guangzhou, Shenzhen and Zhuhai (Pearl River Water Resources Commission of the Ministry of Water Resources China (PRWRC), 2015). Because it is influenced by the East Asian monsoon, Guangdong Province experiences a distinct wet season (April–September), during which the region receives 80% of its annual total rainfall (mean annual rainfall (1981–2010) = 1789 mm; Guangdong Meteorological Service, http://www.grmc.gov.cn/qxgk/tjsj/201310/t20131022_21882.html, in Chinese). Because 13.6% (~30.1 million tons) of the municipal waste that was collected and transported in Guangdong Province in 2014 was not properly treated (National Bureau of Statistics of China (NBS), 2015), it is likely that mismanaged waste will be washed into the waterways more frequently during the wet season than during the dry season, which will result in a seasonal difference in the input of litter into the Pearl River Estuary. Moreover, the prevailing winds in Hong Kong change from southwest in the summer (June–August) to northeast in the winter (December–February). According to Hong Kong Observatory (HKO) (2015), the winter northeast monsoon winds are normally stronger (25.3 km/h) than the summer southwest monsoon winds (21.1 km/h). The abundance and distribution of plastic debris along the estuarine coastline are likely to vary with seasonal changes in the rainfall amounts and wind direction.

This study examines the seasonal variations in the abundance and geographic distribution of plastic debris on Hong Kong beaches. We believe that the Pearl River, which is located west of Hong Kong, plays a crucial role in the spatio-temporal distribution of plastic debris because the west coast of Hong Kong is strongly influenced by the freshwater and litter inputs from this river during the wet season and to a much lesser extent during the dry season, whereas the east coast is not influenced by any major river system and mainly reflects the local and oceanic inputs throughout the year (Fig. 1). The importance of the Pearl River as a source of plastic debris to the waters of Hong Kong may be revealed through this seasonal comparison. In addition, the identification of fluvial sources of marine debris can point to the need for improved waste management practices that prevent litter from entering waterways, both locally and in the Pearl River Delta region.

2. Materials and methods

2.1. Sample sites

A total of 25 sandy beaches in Hong Kong were sampled during both the wet and the dry seasons. Sample collection during the wet and dry seasons was conducted from 7 July to 6 September 2014, and from 16 January to 21 March 2015, respectively. The precipitation during the dry season in Guangdong Province was significantly less than that during the wet season in 2014 (Fig. 1). Of the 25 selected beaches, 14 were located on the west coast of Hong Kong, and 11 were located on the east coast (Fig. 2). The surface salinity distribution in the Pearl River Estuary suggests that the west coast of Hong Kong is strongly influenced by freshwater inputs from the Pearl River during the wet season, whereas the influence of these inputs decreases greatly during the dry season (Fig. 2). The east coast is relatively unaffected throughout the year.

2.2. Sample collection

At each beach, four locations (four replicates per beach) were randomly selected on a 30-*m*-long transect on the high-tide line. At each location, 4-cm-deep surface sediments were evacuated from a 50 × 50 cm quadrat using a metal shovel. The sediment was placed into a graduated plastic bucket and weighed, seawater was added, and the sediment was gently stirred for 30 s to promote floating of the plastic debris (both microplastics and larger plastics). The supernatant was then filtered through a 0.315-mm mesh wire cloth. This process was repeated until no observable plastic debris was recovered. All of the debris that was retained on the wire cloth was carefully transferred to a sealable plastic bag and delivered to the laboratory for further analysis. It is worth noting that plastic polymers with densities greater than that of seawater (~1035 kg/m^3) or brackish water (~1005–1035 kg/m^3), including polyethylene terepthalate (PET; 1370–1450 kg/m^3) and polyvinylchloride (PVC; 1160–1580 kg/m^3), may not have been recovered using this procedure. However, this procedure allows plastic debris to be separated from a large volume of sediment (10 L) and provides more representative samples.

2.3. Identification and counting of plastic debris

In the laboratory, each of the samples was wet-sieved through 5-mm and 0.315-mm test sieves (Endecotts Ltd., London, SW19 3UP, UK). The debris that was retained on the sieves was re-suspended in tap water. Floating and sinking plastic debris was visually identified based on the physical and morphological characteristics of commonly found plastic debris in Hong Kong (Table 1). The identified plastic