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Hong Kong at the Pearl River Estuary: A hotspot of microplastic pollution

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ABSTRACT

Large plastic (>5 mm) and microplastic (0.315–5 mm) debris were collected from 25 beaches along the Hong Kong coastline. More than 90% consisted of microplastics. Among the three groups of microplastic debris, expanded polystyrene (EPS) represented 92%, fragments represented 5%, and pellets represented 3%. The mean microplastic abundance for Hong Kong was 5595 items/m^2. This number is higher than international averages, indicating that Hong Kong is a hotspot of marine plastic pollution. Microplastic abundance was significantly higher on the west coast than on the east coast, indicating that the Pearl River, which is west of Hong Kong, may be a potential source of plastic debris. The amounts of large plastic and microplastic debris of the same types (EPS and fragments) were positively correlated, suggesting that the fragmentation of large plastic material may increase the quantity of beach microplastic debris.

1. Introduction

Plastic is engineered to be durable and inexpensive, and approximately 50% of plastic products, including utensils, plastic bags and packaging, are designed to be disposable (Hopewell et al., 2009). Therefore, a large quantity of plastic waste is generated every year. In 2010, an estimated 275 million tonnes (MT) of plastic waste was generated by 192 coastal countries (Jambeck et al., 2015), which is nearly equivalent to the world production of plastic (265 MT) for the same year as reported by PlasticsEurope (2015). Of the 275 MT of plastic waste, up to 12.7 MT was eventually transported to the ocean because of inadequate waste disposal and littering (Jambeck et al., 2015). Plastic can persist in the marine environment because most plastic is not biodegradable (Andrady, 1994). However, plastic can be broken down into smaller pieces by wave action, hydrolysis and photodegradation in the marine environment (Andrady, 2011; Barnes et al., 2009). Plastic debris with a particle diameter of less than 5 mm is commonly referred to as 'microplastic' (Arthur et al., 2009; Moore, 2008). Although larger plastic debris (>5 mm) has a known impact on marine organisms (Derraik, 2002; Goldberg, 1995), microplastics have been gaining attention in the scientific community over the past decade because they pose a more pervasive threat to the marine environment (Barnes et al., 2009; Browne et al., 2007; Thompson et al., 2004).

Because microplastics are similar in size to sediment and certain plankton, they are harmful to a wide range of marine organisms as they may be mistaken as a food source (Wright et al., 2013). The ingestion of microplastics has been reported in various studies; one of the earliest studies reported the discovery of microplastics in wild fish in the North Atlantic Ocean at different life stages, namely, larvae, juveniles and adults (Carpenter et al., 1972). Under experimental conditions, the ingestion of microplastics has been reported for amphipods, lugworms and barnacles after exposure to microplastics for several days (Thompson et al., 2004). The direct ingestion and accumulation of microplastics in the gastrointestinal system can cause internal abrasions and blockages (Wright et al., 2013). Specific impacts were also identified in zooplankton, which showed a reduced consumption of algae after ingestion of polystyrene beads (Cole et al., 2013), and worms, which demonstrated an impaired ability to manage oxidative stress after ingesting polyvinyl chloride (PVC) (Browne et al., 2013). The possibility of microplastic transference from one organism to another has also been shown. In the Canary Islands, 38 Cory's shearwaters were found to contain an average of 8 plastic items in their guts, including large plastic and microplastic items (Rodríguez et al., 2012). Because their prey are usually 10 cm long and the mean length of plastic found in the shearwaters was only 8.7 mm, the plastic material appeared to have been transferred from their prey (Rodríguez et al., 2012). In the Goiana estuary of Brazil, 13.4% of Gerreidae (N = 425) examined in one study were found to contain nylon fragments ranging from 1 to 5 mm (Ramos et al., 2012). The preferred prey of Gerreidae include amphipods, barnacles and polychaetes (Teixeira and Helmer,

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1997), and these organisms have been shown to ingest microplastics (Thompson et al., 2004). Ramos et al. (2012) suggested that Gerreidae may have obtained nylon fragments from their prey at lower trophic levels. These studies exemplified the concerns expressed by scientists over the bioaccumulation and potential biomagnification of microplastics and associated pollutants in wild populations, which resembles the conditions associated with DDT in the 1940–1970s.

Hong Kong is a metropolis with a population of 7 million, and it is also a coastal city composed of a peninsula and adjacent archipelago of over 250 islands. Hong Kong's aquatic resources include numerous marine recreational zones and bathing beaches that attract millions of visitors every year. Over 20 fish culture zones are distributed in the New Territories and outlying islands, and they contribute to the seafood consumed in Hong Kong. In terms of ecological resources, Marine Parks, including Sha Chau and Lung Kwu Chau, Hoi Ha Wan, Yan Chau Tong and Tung Ping Chau, and the Cape D'Aguilar Marine Reserve were established by legislation in 1996 to protect the diverse marine life and habitats of the marine environment.

However, local and external sources of plastic contamination threaten the marine environment of Hong Kong. The daily amount of plastic waste generated in Hong Kong was 1866 tonnes in 2013, which represented approximately 20% of the locally generated municipal waste (HKEPD, 2015). The use of disposable plastic items, such as food packaging, plastic bags and polystyrene lunch boxes, is common in Hong Kong. Although the city's waste collection and management systems are relatively mature, plastic litter can enter Hong Kong waters directly by wind transport or indirectly through the storm water drainage system as well as through streams and rivers. In addition to local sources, the Pearl River northwest of Hong Kong may be a potential source of the city's plastic pollution. The Pearl River drains an area that includes more than 796,300 km^2 in eight provinces of China, including Guangdong Province (PRWRC, 2015). Nine densely populated cities of Guangdong Province, including Guangzhou, Shenzhen and Zhuhai, are situated in the Pearl River Delta region, which has a total population of close to 60 million. Because three quarters of the waste generated in China is estimated to be mismanaged (Jambeck et al., 2015) and Guangdong Province contributed 13.3% of the plastic production in China in 2014 (NBSC, 2015), the Pearl River is potentially a significant vector of plastic waste transport, particularly during the wet season (May–August), when most of the annual rainfall of approximately 2000 mm occurs (Lee et al., 2006).

To investigate the extent and severity of plastic pollution and provide guidance for remediation measures, the abundance and movement of plastics in the environment must be monitored. Beach surveys represent an indirect but cost-effective method of estimating the abundance and distribution of plastics in the marine environment. In this study, we collected plastic debris, including large plastic (>5 mm) and microplastic (0.315–5 mm) debris, from the beaches of Hong Kong and aimed to establish a baseline for the abundance and geographic distribution of various types of plastic debris, identify the plastic sources, and determine the quantitative relationships among the debris. The following hypotheses were tested in this study: (1) microplastics will be more abundant than large plastics in terms of counts; (2) microplastics will be more abundant on the west coast (consisting of four water control zones, namely Deep Bay, North Western, Southern and Victoria Harbour) than the east coast (consisting of three water control zones, namely Mirs Bay, Port Shelter and Tolo Harbour) of Hong Kong because of its proximity to the Pearl River; (3) microplastic abundance (in number) will be statistically correlated with large plastic debris because fragmentation on the beach is a potential source of microplastics; and (4) microplastic mean abundance in terms of counts per unit area will be higher than the international average because of proximity to urban centres and a large river estuary.

2. Materials and methods

2.1. Study area

More than 500 sandy beaches in Hong Kong were identified from topographic maps and Google Maps. Twenty-five beaches were selected on a stratified sampling basis from seven water control zones (WCZs) (Fig. 1), namely Deep Bay (DB), Mirs Bay (MB), North Western (NW), Port Shelter (PS), Southern (ST), Tolo Harbour (TH) and Victoria Harbour (VH). Each WCZ in Hong Kong has a similar hydrography and ability to assimilate water pollutants. All of the selected beaches were non-gazetted beaches, which means that shark prevention nets are not installed off the beach and beach maintenance does not occur frequently. Beach surveys were conducted between 7th July 2014 and 6th September 2014, a period when Hong Kong waters experienced a significant discharge from the Pearl River.

2.2. Sampling method

At each beach, the high strandline was identified, and four random locations were selected on a 30 m long transect. Sediment to a depth of 4 cm was excavated using a shovel at randomly selected locations from within a 50 × 50 cm quadrat, and the samples were subsequently transferred to a graduated bucket to a total volume of 10 L, thus producing four samples per beach. The sediment was then transferred to another empty bucket in small portions, and seawater was added and stirred gently for one minute so that large plastic was not broken into smaller pieces. The supernatant was filtered through a stainless-steel wire cloth with a 0.315 mm mesh size. This process was repeated until plastic was not found in the supernatant. All of the materials, including large plastic and microplastic items, retained by the wire cloth were transferred to a sealable, labelled plastic bag for further analysis in the laboratory.

2.3. Visual sorting

Each sample was resuspended in a beaker with tap water. The beaker was placed in an ultrasonic bath for five minutes to release plastics that were attached to other marine debris. The sample was then wet-sieved through a 0.315 mm sieve, and the beaker was rinsed with tap water thoroughly to ensure that plastics did not remain. The plastic items were visually sorted using pointed tweezers according to the criteria described by Norén (2007): (1) cellular or organic structures are not contained in the plastics; (2) plastic fibres are equally thick, capable of bending freely and do not taper at two ends; (3) plastic colours are homogeneous and clear; and (4) transparent and whitish items without typical plastic characteristics are examined under a microscope. The items that were identified as 'plastics' were sorted into five groups, with large plastic debris sorted into (1) expanded polystyrene (EPS) and (2) fragments and microplastic debris sorted into (3) EPS, (4) pellets and (5) fragments. All of the plastics were dried completely in an oven at 40 °C before weighing.

2.4. Statistical analysis

The Wilcoxon rank sum test was used to compare the mean and median of the west coast and east coast samples. The sites DB1, DB2 and MB4 (Fig. 1) were excluded from the test because the former two were sheltered by oyster farms and the latter was strongly