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Baseline

Suspended microplastics in the surface water of the Yangtze Estuary System, China: First observations on occurrence, distribution

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A B S T R A C T

Levels of microplastics (MPs) in China are completely unknown. This study characterizes suspended MPs quantitatively and qualitatively for the Yangtze Estuary and East China Sea. MPs were extracted via a floatation method. MPs were counted and categorized according to shape and size under a stereomicroscope. The MP densities were 4137.3 ± 2461.5 and 0.167 ± 0.138 n/m^3, respectively, in the estuarine and the sea samples. Plastic abundances varied significantly in the estuary. Higher densities in three sea trawls confirmed that rivers were the important sources of MP to the marine environment. Plastic particles (>5 mm) were observed with a maximum size of 12.46 mm, but MPs (0.5–5 mm) constituted more than 90% by number of items. The most frequent geometries were fibres, followed by granules and films. Plastic spherules occurred sparsely. Transparent and coloured plastics comprised the majority of the particles. This study provides clues in understanding the fate and potential sources of MPs.

Annual global production of plastic products has increased dramatically from 1.5 million tons in the 1950s to more than 250 million tons in 2011 (Wright et al., 2013). Mass production leads to plastic accumulation in terrestrial and aquatic habitats (Ryan et al., 2009; Thompson et al., 2004), and plastics make up the largest segment of marine litter worldwide (Cole et al., 2011). As a major contaminant, marine plastic not only threatens the safety of maritime activities but also the health of the ecosystem (Maximenko et al., 2012).

In recent years, small-sized plastic debris termed microplastic (MP, fragments less than 5 mm) (Moore, 2008) has been reported as a ubiquitous marine litter. Occupying the size range of plankton, MP is available to a wide range of marine organisms (Lusher et al., 2012). Laboratory and field investigations showed that crustaceans, barnacles, lugworms, mussels, fishes and seals can ingest particles of MP (Boerger et al., 2010; Browne et al., 2008; Cole et al., 2013; Jantz et al., 2013; Murray and Cowie, 2011; Thompson et al., 2004). Ingested MP may result in physical harm within organisms, such as by internal abrasions and blockages. Besides the physical impact, toxicity could also arise from the leaching of plastic additives and POPs that are then absorbed from ambient seawater (Andrady, 2011; Wright et al., 2013).

MPs which enter the marine environment can be of primary (e.g., pellets and abrasive scrubbers used in cosmetics and granules used for air blasting) (Fendall and Sewell, 2009; Thompson et al., 2009) or secondary (breakdown of larger plastic items) origin (Wright et al., 2013). The occurrences of MP have been reported in different marine environments such as beaches, surface waters, water columns, benthic zones and shorelines (Hidalgo-Ruz et al., 2012). Plastics enter the marine environment mostly from land-based sources, often via estuaries (Ivar do Sul and Costa, 2013a). Industrial coastal marine environments and especially estuarine systems have been identified as MP hotspots (Browne et al., 2011; Wright et al., 2013); concentrations of MPs reached 100,000 particles m^3 of seawater in a Swedish harbor area (Norén and Naustvoll, 2010). In terms of abundance, MPs accounted for 65% of debris recorded within the Tamar Estuary, UK (Browne et al., 2010).

As the most important industrial and economic center for China, the region of the Yangtze Estuary is densely populated. Browne et al. (2011) demonstrated that there was a significant relationship between MP abundance and human population density. Due to dense population concentration, river discharge and various maritime activities, the Yangtze Estuary is vulnerable to plastic accumulation. Nevertheless, MPs in the Yangtze Estuary System are almost completely lacking. The objective of the present investigation was to examine the occurrence and distribution of MPs in surface water of the Yangtze Estuary and the adjacent East China Sea (ECS).

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The study was carried out in the Yangtze Estuary and the coastal water of the East China Sea (Fig. 1). The 7 samplings in the Yangtze Estuary were conducted from July 22 to 23, 2013 during the same low tide (Table 1). Fifteen neustonic trawls were collected from August 4 to 9, 2013 in the coastal water of the East China Sea. Depending on its distance from the shore, the designed sampling trawls were divided along five transects (B, C, D, E and F) and into 3 departments: trawls closest to the shore (TCS), trawls intermediate distance to the shore (TIS) and trawls farthest to shore (TFS) (Table 2).

Surface water samples were collected from each location in the Yangtze Estuary using a 12 V DC Teflon pump at a depth of 1 m (Table 1). Two replicate samples were passed through a 32-μm steel sieve. The retained particulate material was washed into 50 mL glass bottles. The samples in the East China Sea were collected using a neuston net with a $30 \times 40\ cm^2$ opening and 333 μm mesh (Ryan et al., 2009) (Table 2). The net was towed along the surface layer at a nominal 2.0 knots (1.75–2.45 knots) for 25–30 min in each transect and towed off the port side of the vessel to avoid disturbance by the bow wave. Contents of the net were washed into a sample jar and fixed in 2.5% formalin (Lattin et al., 2004).

In the laboratory, samples containing large quantities of organic matter were oxidatively cleaned using 30% H_2O_2 (Nuelle et al., 2014). Plastic particles were separated from organic matter by floating in a saturated zinc chloride solution (Liebezeit and Dubaish, 2012). The floating MP particles were filtered over gridded 1.2 μm cellulose nitrate filters. The MPs were enumerated under a dissecting microscope at up to 80× magnification. To avoid misidentification of MPs, we used the criteria applied to define a plastic particle in previous studies (Mohamed Nor and Obbard, 2014; Norén, 2007). Nevertheless, these selection criteria are considered applicable only for MP particles within the size range 0.5–5 mm (Costa et al., 2010; Hidalgo-Ruz et al., 2012). Thus the MP particles with the same range size (>0.5 mm) were enumerated in this study. To avoid airborne contamination, the preventive measures used by Nuelle et al. (2014) were taken in the present study.

Table 1
List of the seven sampling sites in the Yangtze Estuary.

Station	Longitude (N)	Latitude (E)	Volume of water filtered (L)
Y1	31°41.724′	121°10.56′	20
Y2	31°47.004′	120°56.76′	20
Y3	31°30.846′	121°26.46′	20
Y4	31°20.898′	121°39.48′	20
Y5	31°08.778′	121°55.08′	12
D1	31°00′	122°15′	12
D2	31°00′	122°30′	12

Plastic items were widely distributed in the study areas. The average density of MP in the Yangtze Estuary was $4137.3 \pm 2461.5\ n/m^3$ with a range from 500 to $10{,}200\ n/m^3$ (Table 3). Compared to the 32 μm mesh in the Yangtze Estuary, 80 μm meshes were used in the Jade system which may underestimate the plastic particle concentration (Dubaish and Liebezeit, 2013). However, the densities reported here are considerably lower than that in the Jade system ($6.4 \times 10^4 \pm 1.94 \times 10^4\ n/m^3$ for granular particles and $8.8 \times 10^4 \pm 8.2 \times 10^4\ n/m^3$ for fibres). This may be due to two main factors. First, higher river flows in the rainy season from May to October might result in decreases in these pelagic MP items (Ivar do Sul and Costa, 2013a; Williams and Simmons, 1999). The estuarine sampling was after a three-day rain event. Consequently, a significant amount of plastic debris retained in the estuary might have been washed out to the sea. Secondly, the limited water volume filtered may contribute to the low particle density. The MP distributed heterogeneously in the water body (Dubaish and Liebezeit, 2013). Small sampling volumes may miss debris present in the estuary.

Variability in the density of particles were apparent in the estuarine samples (Kruskal–Wallis test, $p = 0.013 < 0.05$). The maximum density value ($8550 \pm 1788\ n/m^3$) was obtained at the Y1 site (Xuliujing) where the discharge could be considered the total discharge into the estuary (Chen et al., 2013). Y3, Y4 and Y5 had intermediate densities that were added by plastic particles from the Yangtze tributaries (Fig. 2). The results agreed that

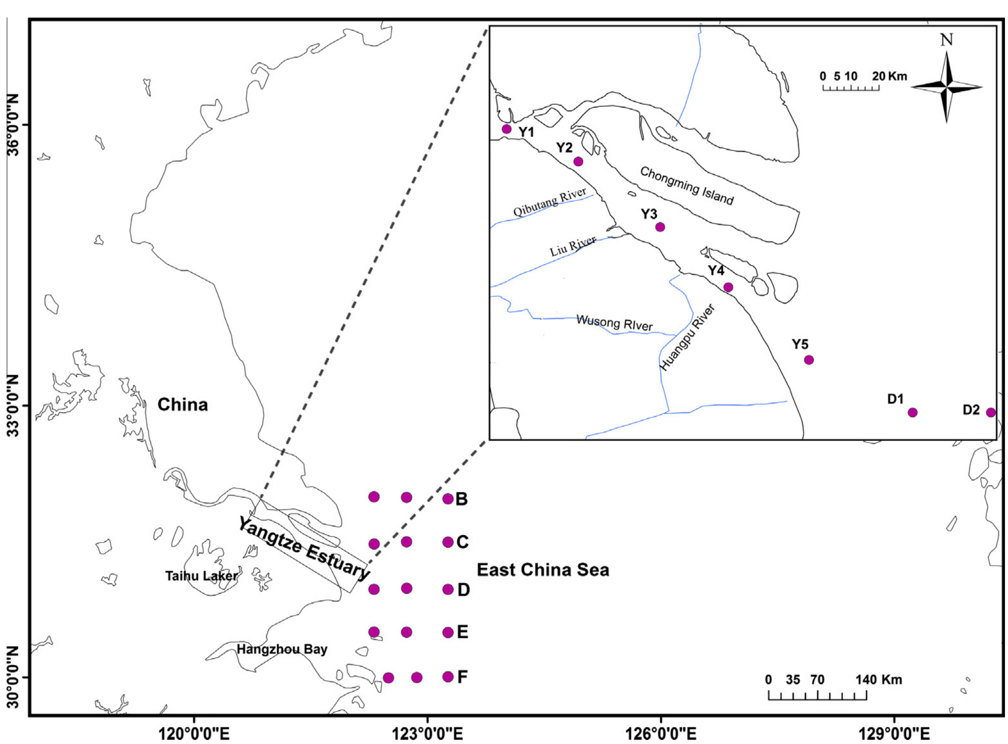

Fig. 1. Research area in the Yangtze estuarine system with the sampling sites and trawl stations for microplastic.