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Characterization, source, and retention of microplastic in sandy beaches and mangrove wetlands of the Qinzhou Bay, China

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ABSTRACT

Severe microplastic pollution from anthropogenic activities in coastal zones presents an imminent risk to marine ecosystems. In this study, abundant microplastics (15–12,852 items kg^{-1}) with sizes ranging between 0.16 and 5.0 mm were extracted from 17 sediment samples collected in sandy beaches and mangrove wetlands of the Qinzhou Bay, Guangxi Province, Southwest China. Three types of microplastics (i.e. polystyrene, polypropylene, and polyethylene) were identified with Fourier transform infrared (FTIR) spectroscopy analysis. These detected microplastics were characterized by different colors (white, transparent, yellow, green, red, and blue) and shapes (fragment, fiber, and sphere). Microplastics were concentrated on supratidal beaches and wetlands outside of mangrove, and less abundant on intertidal beaches and inside of mangrove wetlands. Meanwhile, high microplastic concentrations were observed near mollusk farms. The spatial distribution and chemical speciation indicated that microplastics were derived from disintegration of large plastic debris (e.g., Styrofoam buoys used to support mollusk rafts) abandoned by aquaculture industry. Further, coastal vegetation (e.g. mangrove) could trap microplastic particles.

1. Introduction

Microplastics have been ubiquitously detected in water, sediments, and beaches, at high concentrations (Moret-Ferguson et al., 2010; Woodall et al., 2014; Fok et al., 2017). Due to their size similarity to algae and sediment, microplastics can be ingested by plankton, bivalves, lobster, fish, and accumulate in food webs (Lee et al., 2013; Wright et al., 2013; Bakir et al., 2014; Ivar do Sul and Costa, 2014; Van Cauwenberghe and Janssen, 2014). The toxic additives contained in plastics can be released to the environment, then causing potential harm to organisms (Koelmans et al., 2014). Meanwhile, microplastics are also considered as carriers of various toxins and hydrophobic organic pollutants (Guo et al., 2012; Batel et al., 2016; Hueffer and Hofmann, 2016; Li et al., 2018).

Land-based sources and maritime activities can carry large loads of plastic debris to coastal environments (Li et al., 2016; Auta et al., 2017). Numerous studies have determined that microplastics concentrations on sandy beaches and subtidal sediments are extremely high (Lee et al., 2013; Dekiff et al., 2014; Mathalon and Hill, 2014; Yu et al., 2016). Furthermore, recent studies have identified high abundance of microplastics in mangrove and salt marsh habitats and suggested that the vegetation of wetlands is an effective retaining media of microplastics (Nor and Obbard, 2014; Sutton et al., 2016; Weinstein et al., 2016). Therefore, coastal wetlands might be an important reservoir of microplastics. Qinzhou Bay is located on the coast of Guangxi Province, southwest China and is the largest natural breeding areas of *Magallana rivularis* (Gould, 1861). There are > 23,000 acres of mollusk farming located in this area. Styrofoam floats are intensively used in hanging-culture farms for mollusk. Intensive aquaculture activities may make the Qinzhou Bay a hotspot for microplastics pollution. The intertidal zones of the inner bay and adjacent coastlines are dominated by mangrove forests, which may influence the retention of microplastics. Furthermore, high temperature and strong solar ultraviolet light associated with tropical climate can accelerate the degradation of plastic debris in coastal zones (Heo et al., 2013). However, there is currently no data can reveal the source and retention of microplasitc pollution in coastal zones of the Qinzhou Bay.

This study aimed to investigate microplastic pollution in the Qinzhou bay. 17 sediment samples were collected to determine the occurrence and spatial distribution of microplastics. Microplastics were

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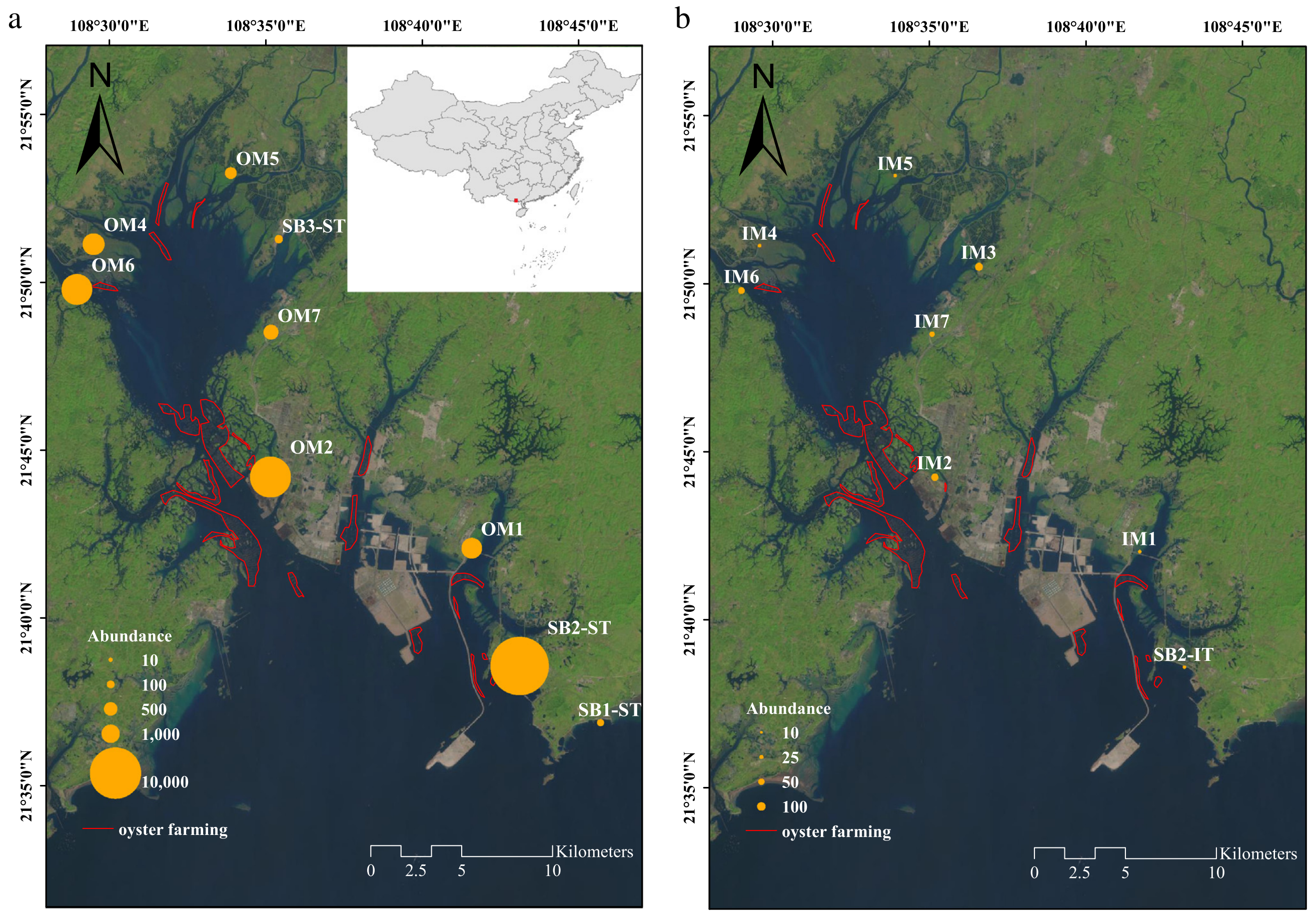

Fig. 1. Geographical location of the Qinzhou Bay and the sampling locations illustrated with microplastics concentrations. Note: The image of Qinzhou Bay obtained from Landsat 8 satellite (December 2016). The red lines indicate locations of mollusk farming. To make Fig. 1 clear, it was divided to Fig. 1a and Fig. 1b based on the sampling locations. Fig. 1a: abundance of microplastics in supratidal sandy beaches (SB-ST) and samples outside mangrove (OM); Fig. 1b: abundance of microplastics in intertidal sandy beaches (SB-IT) and samples inside mangrove (IM). Unit is items kg^{-1}. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

counted and characterized according to their type, shape, size, and color. Based on field data, we discussed the dominant sources and retention of microplastics.

2. Materials and methods

2.1. Sampling and processing

A total of 17 sediment samples were collected in the Qinzhou Bay from December 18, 2016 to December 21, 2016. The sampling sites were illustrated in Fig. 1a and b, and the detail information of each sampling site was listed in Table S1. At low tide, sandy and muddy sediment samples were collected from the top 2 cm. Samples were taken from five separate 0.3 m × 0.3 m quadrats and then homogenized. The air-dried samples were sieved using a stainless-steel mesh with pore size of 35 mesh (i.e. 5 mm) to remove the large particles (i.e. > 5 mm).

2.2. Microplastic extraction

Microplastics were extracted from beach sand and mangrove sediment samples using a modified flotation device (Fig. S1) based on Nuelle et al. (2014). According to the published studies (Nor and Obbard, 2014; Stolte et al., 2015; Karlsson et al., 2017), calcium chloride solution with a density of 1.38 g cm^{-3} was selected and used as concentrated saline solution to float microplastics. Briefly, 500 g of beach sand sample or 100 g of mangrove sediment sample were transferred into a 2.5 L beaker and then mixed with 2 L of concentrated saline solution. Sodium metaphosphate was added to mangrove sediment samples to prevent aggregation. The mixture was stirred using a glass stick for 15 min, meanwhile turn on the aeration pump to accelerate the separation of microplastics and sediments. A settling time was setted for 24 h. Then, the solution was sieved using a stainless-steel mesh with pore size of 300 mesh (i.e. 50 μm) with the help of peristaltic pump (WT600-2 J, LONGER). The extraction of each sample was repeated twice. The plastic particles were identified using a magnifier with a magnification of 10×. The properties used to identify plastics were based on published studies (Nor and Obbard, 2014; Peng et al., 2017). Identified microplastics were transferred to black cardboard and then photographed using a digital camera (EOS 60D, Canon). The photos were analyzed using software ParticleMFC which developed based on MATLAB 8.0 (Mathworks, Inc., Natick, MA) to count number of microplastics and measure the particle size and shape. Quality control and quality assurance was performed as described by Zhao et al. (2015) and Naji et al. (2017). Before extraction, the recovery experiment was conducted to evaluate the efficiency of this flotation device. Briefly, 150 particles belong to 5 types of plastic debris with particle size ranging from 0.5 to 5 mm were mixed with 500 g of clean sediment. The samples were extracted using the flotation equipment twice. Results show that the recoveries of five classes of microplastics ranged from 86.7%–100% (Table S2).