Science of the Total Environment 634 (2018) 811–820

Contents lists available at ScienceDirect

Science of the Total Environment

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

Microplastics and polycyclic aromatic hydrocarbons (PAHs) in Xiamen coastal areas: Implications for anthropogenic impacts

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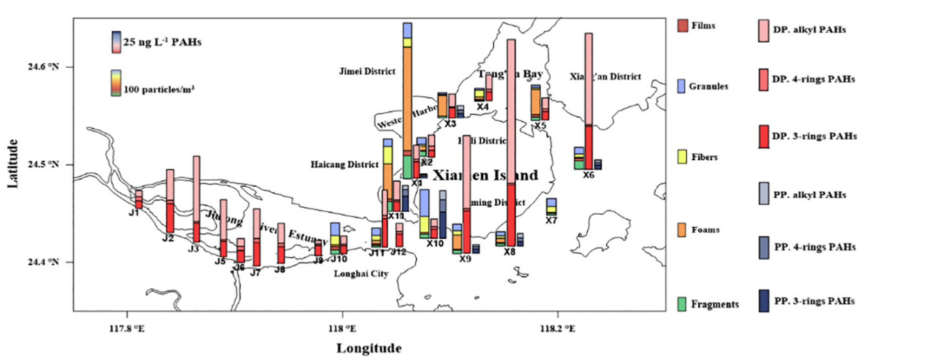
HIGHLIGHTS

- Microplastics and PAHs were observed in the marine environments in Xiamen coastal areas.
- The abundance of microplastics showed a geographical variety, which was dominant in the Western Harbor.
- Relationships among different types of microplastics and PAHs were derived from the cluster analysis.
- Correlation analysis illustrated the possible influence of human activities on microplastics.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 29 January 2018
Received in revised form 27 March 2018
Accepted 27 March 2018
Available online xxxx

Keywords:
Microplastics
POPs
Cluster analysis
Correlation analysis
Human activities
Southeast China

ABSTRACT

Microplastics and polycyclic aromatic hydrocarbons (PAHs) were investigated to study the influence of human activities and to find their possible relationship on the coastal environments, where the coastal areas around Xiamen are undergoing intensive processes of industrialization and urbanization in the southeast China. The abundance of microplastics in Xiamen coastal areas was 103 to 2017 particles/m^3 in surface seawater and 76 to 333 particles/kg in sediments. Concentrations of dissolved PAHs varied from 18.1 to 248 ng/L in surface seawater. The abundances of microplastics from the Western Harbor in surface seawater and sediments were higher than those from other areas. Foams were dominated in surface seawater samples, however, no foams were found in sediments samples. The microscope selection and FTIR analysis suggested that polyethylene (PE) and polypropylene (PP) were dominant microplastics. The cluster analysis results demonstrated that fibers and granules had the similar sources, and films had considerably correlation with all types of PAHs (3 or 4-ring PAHs and alkylated PAHs). Plastic film mulch from agriculture practice might be a potential source of microplastics in study areas. Results of our study support that river runoff, watershed area, population and urbanization rate influence

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https://doi.org/10.1016/j.scitotenv.2018.03.336

the distribution of microplastics in estuarine surface water, and the prevalence of microplastic pollution calls for monitoring microplastics at a national scale.

1. Introduction

Plastics have been widely produced and used with enormous demands, and million tons of them finally enter into the oceans (Eubeler et al., 2010; Tosin et al., 2012). Microplastics, normally defined as plastic debris with a diameter <5 mm, originate from intentional manufacture (primary origins) or the subsequent fragmentation (secondary origins) (Fendall and Sewell, 2009; Wright et al., 2013). A large number of microplastics have been found in the seawater (Cole et al., 2011; Zobkov and Esiukova, 2017), beaches (Claessens et al., 2011; Liebezeit and Dubaish, 2012), and sediments (van Franeker et al., 2011; Van Cauwenberghe et al., 2013; Obbard et al., 2014). It has been proposed that the accumulation of floating plastic debris in different time intervals results from the combined effect of sedimentation, shore deposition, fragmentation and ingestion processes (Peng et al., 2017).

The widespread microplastics in the environment have become a hot spot since they may well exert a physical damage on the marine biota, such as internal abrasions and blockages. Moreover they have the special affinity for organic pollutants (Andrady, 2011; Wright et al., 2013), among which polycyclic aromatic hydrocarbons (PAHs) are one of the most widespread contaminants which have mainly pyrogenic sources. PAHs could pose serious risk to human health due to their toxicity, carcinogenicity and mutagenicity (Cai et al., 2016a). Therefore, microplastics play a role in aquatic ecotoxicology as vectors for these toxic substances, though the bioavailability of these pollutants carried by microplastics has not been studied in detail (Moore, 2008; Hartmann et al., 2017). The coastal or estuarine environments with mass industries and agricultural activities are considered as key areas for contaminants, such as for microplastics and organic pollutants (Browne et al., 2011; Wright et al., 2013). Compared to the beaches, seawater and sediments were the major living environment for the marine biota. Along the coastline in China, the first quantitative study of microplastics was conducted in 2013, and it focused on the seawater near the Yangtze River Estuary (Zhao et al., 2014). Besides, several studies have been reported in recent years focusing on the seawater, sediments in Yangtze River Estuary, Pearl River Estuary, Minjiang River, where massive abundance of microplastics were found (Qiu et al., 2015; Zhao et al., 2015; Peng et al., 2017).

Xiamen is a developing coastal city located in the front of the Jiulong River Estuary, the second largest river in Fujian province, China. As one of the four special economic zones, Xiamen has accomplished remarkable social and economic achievements since the early 1980s. Rapid population growth and intense industrial activities in Xiamen have led to huge pressure on coastal ecosystem stability, which attracts growing attention from the government, the public and academy (Ren et al., 2011; Ma et al., 2016; Huang et al., 2017). In addition, the Xiamen coast receives large amounts of waste from the Jiulong River Basin, where a developed agricultural region is located (Cao et al., 2005; Peng et al., 2013). This further deteriorated local ecological situation. On that account, Xiamen was select as a demonstration plot in East Asia for integrated coastal management since 1994, to explore the way to balance multiple use conflicts from both land and sea, and to control pollution sources (Cai et al., 2016b). The coastal environment situation of Xiamen coast has been the subject of extensive study and government efforts for rehabilitation. Some pollutants and their related ecological influence in Xiamen coast have been reported, such as nutrients (Cai et al., 2016b), heavy metals (Chen et al., 2010), PAHs (Ya et al., 2014), pesticide (Wu et al., 2017) and antibiotics (Zheng et al., 2011). However, there is few information about the microplastics pollution. Therefore, for effective management decision, it is urgent to investigate the microplastics in Xiamen coast and its relationship with human activities. The aims of this study are as follows: 1) to investigate the abundance and distribution of microplastics and PAHs in Xiamen coastal areas, including Xiamen Bay and the Jiulong River Estuary. 2) to find their possible relationship by using cluster analysis. 3) to identify the sources of microplastics and see their relationship with human activities.

2. Materials and methods

2.1. Study areas

Xiamen has an area of about 1700 km^2 and a population of near 4 million. It is an important harbor city located on the southeast coast of Fujian Province, China. The study areas can be divided into 3 different parts (Fig. 1), i.e. the Western Harbor (including X1–5 and X11–12), the Open Sea that located at the eastern part of Xiamen Island (including X6–8), and the Jiulong River Estuary (including J1–J12 and X9–10). The Western Harbor is a dumbbell-shaped semi-enclosed bay located at the Western side of Xiamen Island (Cai et al., 2016b). The Jiulong River is the second largest river in Fujian Province, which has a basin area up to 14,700 km^2 and supports over 5 million populations. The open sea is located at the eastern side of Xiamen Island, where is significantly affected by the seawater outside.

Since the policy of reform and opening has been implemented for 40 years, Xiamen has become one of the most developed and populous areas in China. Intense economic activities and rapid population growth, however, have led to strong anthropogenic stress on coastal ecosystems. This area receives not only most of domestic sewage (partially untreated) and industrial wastewater from Xiamen coast, but also the agricultural runoff from the Jiulong River Basin that carries great amounts of fertilizers and pesticides.

2.2. Sampling and pretreatment for microplastics

2.2.1. Microplastics in surface seawater

All the samples were collected in March 2017 in the Western Harbor and the Jiulong River Estuary (Fig.1). Surface seawater samples (X1–11 and J10–11) were collected using a manta trawl (1 m wide × 0.5 m vertical opening, 3 m long, 0.33 mm mesh) (Ryan et al., 2009). The net was towed a straight line with the vessel speed being kept at an average of 2 knots for 10 min (Table S2) and the top 35–50 cm of the water column was collected. A calibrated flow meter (HYDRO-BIOS, Germany) was attached to the mouth of the net to allow for volume calculation of the water filtered. The contents of the net were then washed into a precleaned glass jar with Milli-Q water, and fixed in 2.5% formalin for further laboratory processes (Lattin et al., 2004).

In the laboratory, the large debris (>5 mm) were screened with a 5 mm steel-wire sieve and discarded. The rest were filtered onto nylon filters (Millipore, 20 μm), and were oxidatively conducted using 30% H_2O_2 (Nuelle et al., 2014). After filtered with nylon filters (20 μm), plastic particles were separated via flotation in NaCl solution (with a density of 1.2 g/cm^3) for 24 h, and then the supernatant was collected for further analysis (Hidalgo-Ruz et al., 2012).

2.2.2. Microplastics in surface sediments

The samples were collected with a box grab at 8 stations (J1–5, J12, X3 and X12) in April 2017 (Fig. 1). And then all surface sediments samples (<5 cm) were shoveled with a clean stainless steel spoon and stored