Science of the Total Environment 644 (2018) 375–381

Contents lists available at ScienceDirect

Science of the Total Environment

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

Occurrence and distribution of microplastics in an urban river: A case study in the Pearl River along Guangzhou City, China

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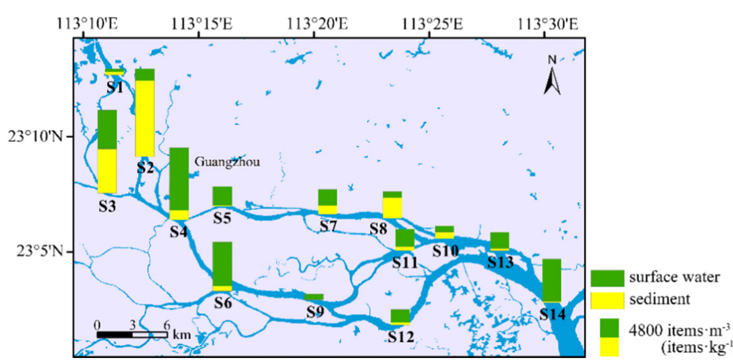
HIGHLIGHTS

- Microplastics in the Pearl River along Guangzhou were investigated for the first time.
- Fibers were detected in both surface water and sediment samples.
- PE and PP were the dominant polymer types in surface water and sediments.
- WWTP in Guangzhou could reduce microplastic pollution in the municipal sewage.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 6 May 2018
Received in revised form 24 June 2018
Accepted 26 June 2018
Available online xxxx

Editor: Jay Gan

Keywords:
Microplastics
Surface water
Sediment
Pearl River
Wastewater treatment plants

ABSTRACT

Microplastics, as emerging contaminants in the global environment, have become a cause for concern for both academics and the public. The present understanding of microplastic pollution is primarily focused on marine environments, and less attention has been given to freshwater environments, in particular, to urban rivers. In this study, microplastics were sampled from surface water and sediments in 14 sites located in the lower course of the Pearl River. These sampling sites are located along Guangzhou of South China, with built-up areas being the dominant land use. The abundances of microplastics in surface water and sediments ranged from 379 to 7924 items$\cdot$m^{-3} and 80 to 9597 items$\cdot$kg^{-1}, respectively. Polyethylene and polypropylene were the common types of microplastics, together accounting for 64.3% and 73.8% of surface water and sediment samples, respectively. Fibers were the dominant microplastic shapes in both water and sediment samples. The abundances of microplastics varied in surface water and sediments with each site, which might be affected by multiple factors. Our results indicated that wastewater treatment plants (WWTP) could reduce microplastics from municipal sewage which was finally discharged into the Pearl River along Guangzhou.

1. Introduction

In the recent decades, microplastic pollution, identified as a global environmental problem, has attracted increasing public attention. Microplastics (MP) are defined as plastic debris that is <5 mm in

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https://doi.org/10.1016/j.scitotenv.2018.06.327
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diameter (Cole et al., 2011). There are two types of MP, primary and secondary. Primary MP refers to the plastics manufactured purposefully in small size. Examples include microbeads used in personal care products and media used in air-blasting technology (García and Muñoz-Vera, 2015). Secondary MP are derived from fragmentation of large plastic debris due to photodegradation, mechanical weathering (wind, wave, sand, etc.), as well as chemical and biological processes in environments (Fendall and Sewell, 2009; Peters and Bratton, 2016). The resultant widespread presence of MP in terrestrial and aquatic environments could be ingested mistakenly as food by a wide range of organisms, including zooplankton (Jemec et al., 2016), fish (Phillips and Bonner, 2015), birds (Lourenço et al., 2017), turtles and mammals (Hutton et al., 2008). In addition, MP could release toxic chemicals that were added as additives during the manufacture process, and/or sorb pollutants from the ambient environment. Thus, contaminants associated with MP could be transferred into the bodies of biota and even up to higher trophic levels through the food chains (Ward and Kach, 2009), resulting in potential threats to organisms and ecological environments (Rummel et al., 2017).

The occurrences of MP in terrestrial, freshwater, estuarine, coastal and marine environments have been reported (Van Cauwenberghe et al., 2013). The riverine and estuarine environments, in particular, have been identified as hot spots of MP pollution (Eerkes-Medrano et al., 2015; Peng et al., 2017). Rivers especially those flowing through big cities were considered as major sources of land-based MP into oceans (Eerkes-Medrano et al., 2015). Plastic wastes from populated areas within the watershed were washed into the rivers due to littering and poor waste management practice (Browne et al., 2011; Wagner et al., 2014). It was estimated that 1.15 to 2.41 million tons of plastic debris from worldwide rivers discharged into the oceans every year (Lebreton et al., 2017). Fok et al. (2017) estimated that approximately 209.7 trillion microbeads (306.9 t) emitted every year into aquatic environments from the Mainland China and >80% of which originated from wastewater treatment plants. The omnipresence nature together with the observed intensity of MP pollution urges investigations in the fluvial environments. Nonetheless, there is relatively less information with regard to MP pollution in urban rivers (Hoellein et al., 2017; Wang et al., 2017a; Yonkos et al., 2014).

Guangzhou, the capital city of Guangdong Province, is a megacity in South China with >14 million permanent residents in 2016 (Guangzhou Statistics Bureau). The city produced 4.63 million tons of solid wastes and 1.62 billion tons of wastewater in 2015 (Guangzhou Environmental Protection). Although solid wastes and wastewater were properly managed in Guangzhou, the small-sized MP might be released into the Pearl River through runoff, sewage discharge, industrial effluents, and atmospheric deposition. It was estimated that 13.6 thousand tons of plastic wastes were discharged from the Pearl River into South China Sea every year (Lebreton et al., 2017). The Pearl River therefore, plays an important role in the MP sources, transport and accumulation. As a result, the Pearl River Estuary and its adjacent sea areas have become hotspots of MP pollution (Cheung et al., 2016; Fok and Cheung, 2015; Fok et al., 2017). Although MP abundance in the surface sediments from the Beijiang River (a tributary of the Pearl River) was reported (Wang et al., 2017b), information on MP pollution in the Pearl River especially along the megacity with a high population density such as Guangzhou is still unknown. Therefore the knowledge gap called for the needs of this study, in which the abundance and spatial distribution of MP were investigated in surface water and sediments in the Pearl River along Guangzhou. The potential sources of MP and influential factors were also discussed.

2. Materials and methods

2.1. Sample collection

Guangzhou section of the Pearl River, which originates from the Liuxi River at the upper reaches locates at the west and south parts of Guangzhou. The Pearl River flows through the central built-up area of Guangzhou and finally turns to the south towards the Pearl River Estuary in the South China Sea (Fig. 1). MP samples in the surface water and sediments were collected from 14 sampling sites in this river section in July 2017. At each site, 60 L bulk surface water samples were collected with a 5 L water sampler (Seaward WS-5, Guangzhou, China) by vertically putting it into the river under the water surface. Surface water at the top 50 cm was collected by a sampler and then filtered through a wire wound stainless steel sieve with mesh size of 0.02 mm. The size ranges of MP in this study were focused on 0.02–5 mm. The suspected MP were separated from a bulk of surface water in the field for the following reasons: (1) To avoid plankton influence on the samples. Surface water was filtered in field and their residues were fixated with formaldehyde solution. (2) To avoid transporting a large amount of water samples back to the laboratory. Benthic sediments were collected with Van Veen grab sampler (HYDRO-BIOS 437330, Kiel, Germany) at each sampling site. A total of 2 kg surface sediments on the top 5 cm were collected randomly from the sampler and put into an aluminum foil bag. The sediment samples were taken back to the laboratory on the same day and stored at −20 °C in the laboratory for subsequent analysis.

Microplastics in wastewater were investigated in three large wastewater treatment plants (WWTP) in Guangzhou City (Fig. 1). The sewage treatment capacities of these WWTP are 0.55, 0.20 and 1.20 million tons (MT) per day in W1, W2, and W3, respectively. The main treatment technology of these WWTP is anaerobic-anoxic-oxic (A^2/O) process, which includes coarse screening, upgrade pumping, fine screening, sedimentation, activated sludge treatment, second sedimentation, sterilization, etc. The influent water (15 L) after coarse screening and effluent water (15 L) after the sterilization were collected in each WWTP and filtered immediately in the laboratory according to the method described by Leslie et al. (2017).

2.2. Extraction of microplastics

In the laboratory, the digestion, separation and analysis of MP from water and sediment samples were conducted following an adjusted protocol (Su et al., 2016). In brief, water samples collected from the Pearl River or WWTP were filtered again through a clean 20 μm membrane filter under vacuum in order to reduce the water and the fixative. Residues with the membrane filters were transferred into a 1000 mL conical flask, in which 200 mL of hydrogen peroxide (30%, v/v) solution was added to digest the organic substances on the surfaces of samples. These conical flasks were then covered with aluminum foils and placed in an incubator shaker at 65 °C and 80 rpm for 24 h. After digestion, 800 mL of saturated NaCl solution (1.2 $g \cdot mL^{-1}$, 25 °C) was added to each bottle to separate MP for another 24 h at the room temperature. Finally, the water samples were vacuum filtered through a 5 μm membrane filter to collect all of the suspected MP. The filter was covered with a clean petri dish for further observation.

Wet sediments stored in an aluminum bag were transferred into a clean aluminum disk and dried at 60 °C to a constant weight for 48–72 h. During the drying process, these disks were covered with aluminum papers to minimize air-borne contamination. The dried sediment was manually and gently crushed to disaggregate the cake. Large items including rocks, wood, sand and large plastic debris were also removed in the process. In each disaggregated sediment sample, a total of 200 g sediments were sub-sampled randomly, weighed and placed into a conical flask, in which 1000 mL saturated NaCl solution was added. The sample was stirred with a glass rod for 5 min, covered with an aluminum foil and remained still for 24 h for density separation. Here, the supernatant was decanted rather than extracted with pipette for the sake of improved efficiency following a previous study (Näkki et al., 2017). The floatation and extraction procedures were repeated several times in order to obtain the maximum amount of MP from sediments. The supernatant was vacuum filtered through a 20 μm