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Microplastics in surface waters and sediments of the Three Gorges Reservoir, China

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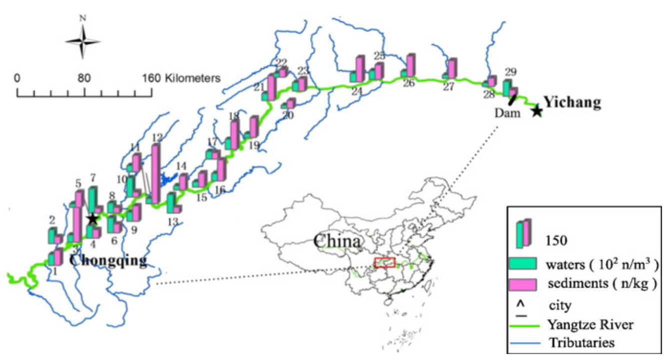
HIGHLIGHTS

- Microplastics were studied in the largest reservoir from China.
- Residential and sewage treatment plants affected microplastic concentrations.
- There was no significant correlation between microplastic concentrations in each sampling site.
- The high-densitiy microplastics were more likely to deposit in the sediment.

GRAPHICAL ABSTRACT



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ABSTRACT

We investigated microplastic pollution levels in surface waters and sediments from the Three Gorges Reservoir (TGR). The TGR is the largest reservoir in China and is located across the Chongqing municipality and Hubei Province. Microplastic abundance in the surface water ranged from 1597 to 12,611 n/m^3 and in the sediments was 25 to 300 n/kg wet weight (ww). In the surface waters, the contamination was more serious in urban areas, and in the sediments, countrysides were the most heavily polluted areas. Fibers were the most abundant microplastics, the dominant color was transparent, and small-sized particles were predominant. Of all the microplastics identified by micro-Raman spectroscopy, polystyrene was the most common type (38.5%) followed by polypropylene (29.4%) and polyethylene (21%). Compared with low-density microplastics, the high-density ones were more likely to be deposited from the water into the sediment. Several contaminants adsorbed by microplastics, such as organic solvents and pharmaceutical intermediates, were observed and qualitatively analyzed by Raman spectroscopy. The results of this study could provide valuable background information for microplastic pollution in the TGR.

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1. Introduction

For decades, plastic products have brought great convenience to our daily life but are accompanied by serious environmental pollution problems (Derraik, 2002; Fendall and Sewell, 2009; Thompson et al., 2009; Yamada-Onodera et al., 2001). After degradation in the terrestrial and

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marine environment, plastic items eventually break down into millions of small plastic particles (Cozar et al., 2014; Fendall and Sewell, 2009), and those with a size of <5 mm are defined as microplastics (Moore, 2008). Billions of microplastics have been found in the oceans, rivers and lakes and even in inaccessible locations such as the Arctic and the Southern Ocean (Browne et al., 2011; Dekiff et al., 2014; Derraik, 2002; Eriksen et al., 2013; Isobe et al., 2017; Lusher et al., 2015b; Su et al., 2016; Zhao et al., 2015). As reported by previous research, microplastics can transfer pollutants and pose a potential risk to aquatic organisms, seabirds, turtles and mammals (Browne et al., 2013; Di Beneditto and Ramos, 2014; Endo et al., 2005; Gall and Thompson, 2015; Hoarau et al., 2014; Lusher et al., 2015a; Ogata et al., 2009; Santos et al., 2015; Setälä et al., 2014; von Moos et al., 2012).

In comparison with the wealth of data on microplastic pollution from the oceans, information regarding those from freshwater environments is minimal (Wagner et al., 2014). The first report on microplastic pollution in freshwater (Californian rivers) appeared in 2005 without a peer review (Moore et al., 2005). Recently, several studies on rivers have provided evidence that plastics are inputted via the river into the sea (Lechner et al., 2014; Moore et al., 2011; Morritt et al., 2014; Rech et al., 2014; Zhao et al., 2015; Zhao et al., 2014) and thus contribute substantially to marine (micro)plastic pollution (Wagner et al., 2014). In the past few years, microplastics have been detected in the surface waters and sediments in several lakes (Driedger et al., 2015; Eriksen et al., 2013; Su et al., 2016; Wang et al., 2017; Zbyszewski and Corcoran, 2011; Zbyszewski et al., 2014). However, to date, knowledge of the accumulation and impacts of microplastics in freshwater and terrestrial systems is much less than in marine systems.

Dams fragment rivers and offer society many benefits but also cause multilevel effects throughout the aquatic ecosystem (Tullos, 2009). As a result of impoundment, reservoirs may be a potential area for the accumulation of microplastics (Zhang et al., 2015). The Three Gorges Reservoir (TGR) is by far the largest reservoir in China with a total water surface area of 1080 km^2 in the Yangtze River between Chongqing Municipality and Yichang (Zhang and Lou, 2011). This unique river-style reservoir is situated in an economically booming area, and continuing efforts of the sewage disposal and pollution prevention system can hardly keep up with developing urban areas and industries along the river (Holbach et al., 2013). Many anthropogenic pollutant sources have developed since the impoundment of the Three Gorges Dam (TGD) such as industrial and household sewage, wastewater treatment plant (WWTP) discharges, garbage dumping, and agricultural pollution (Chang et al., 2010; Tian et al., 2010). Thus, many environmental and ecological problems have emerged in the TGR such as heavy metals and organic pollutants (Ma et al., 2016; Wolf et al., 2013). As an emerging pollutant, the distribution of microplastics near the dam (Zigui County) has been reported (Zhang et al., 2015; Zhang et al., 2017). However, there is no relevant information regarding microplastic pollution in the entire reservoir area. In the present study, surface water and sediment samples were collected along the river covering Chongqing and parts of Hubei Province (up to the dam). We investigated microplastics in these samples and found various levels of microplastic pollution in the TGR. This investigation focused on the spatial distribution of microplastics in the TGR ecosystem and may provide a valuable reference for understanding the microplastic pollution in a river-style reservoir. In particular, we identified several chemical pollutants adsorbed by microplastics from the TGR, and the potential impacts of the microplastic-pollutant complexes in reservoir ecosystems are discussed.

2. Materials and methods

2.1. Study areas and sampling sites

From the Tibetan Plateau to Shanghai, the Yangtze River covers agricultural and industrial terrain of 1,810,000 km^2 with a population of 450 million people (Yang et al., 2005). The TGD was completed in 2009 and formed the biggest reservoir in China. The region surrounding the reservoir (approximately 58,000 km^2) has become known as the Three Gorges Reservoir Region (TGRR) (Zhang and Lou, 2011). In the TGRR, the Yangtze River flows through areas of different population densities, agricultural zones, manufacturing districts and nature reserves. In this study, we chose 29 sampling sites along the Yangtze River from Chongqing to Yichang. These sites were located in 17 counties (or districts) including urban, suburban and rural areas. The surrounding environments of these sampling points are diverse and represent different regions of the TGR such as docks, parks, hospitals, sewage treatment plants and the confluence of tributary and the main stream. Details of each site are shown in supplementary materials Table S1.

2.2. Sample collection

The sampling sites were located near the center of the main stream. Water and sediment samples were collected in August 2016. Briefly, 25 L of surface water was collected from each location using a clean 12 V DC Teflon pump at a depth of 1 m and then filtered with a 48 μm stainless steel sieve (Wang et al., 2017; Zhao et al., 2014). The materials blocked by the sieve were washed into a 50 mL glass jar using pure water. Before laboratory analysis, the samples were fixed in 5% formalin at 4 °C (Lattin et al., 2004). Two replicates were taken at each site. The sediments obtained from the riverbed were used to assess the presence of microplastics (Claessens et al., 2011). At the same site, approximately 1 L of sediment was collected with a Van Veen grab (0.25 m^2 sampling surface), placed in a glass jar and then preserved at 4 °C before analysis. Two replicates were taken at each site. Contact with plastic materials was avoided at all times to prevent contamination. All of the sampling tools were cleaned between each site. In addition, the water samples were labeled as the W series such as W1 and W2, and the sediment samples were marked as the S series.

2.3. Sample preparation

To dissolve natural organics, all of the water samples were treated with 30% H_2O_2 for 12 h (Liebezeit and Dubaish, 2012). Next, each sample was filtered through a gridded 0.45 μm glass microfiber filter paper (GF/F, 47 mm Ø, Whatman) under a vacuum. Then, the filter paper was placed in a covered glass dish and dried in the oven at 50 °C while waiting for microscopic examination (Wang et al., 2017).

The microplastics in the sediments were extracted by applying a two-step density separation method (Nuelle et al., 2014; Thompson et al., 2004) with some modifications. First, 1 L of saturated sodium chloride solution was added to 500 g of wet sediment in a glass beaker (2 L), stirred for 2 min and settled for 10 min. Then, the supernatant was poured through a 48 μm stainless steel sieve and the microplastics intercepted by the sieve were washed into a beaker, which was subsequently covered with tin foil. It is recommended that the filtered sodium chloride solution should be recycled. This extraction was performed three times for each sample. The purpose of this preliminary extraction was to reduce the sample mass for the next step since sodium iodide is very expensive and not eco-friendly. The aim of the second step was for further extraction of high-density microplastics. After the first extraction step, the remaining sediment was collected and transferred to a triangular flask (500 mL) and a 60% sodium iodide solution was added to 3/4 of the flask. The mixture was then shaken for 2 min at 200 rpm on a shaker and permitted to stand for 10 min. After stratification, the supernatant treatment was the same as the first step. It is recommended that the used sodium iodide solution should be recycled. For each sample, the process of refilling, shaking, precipitation and decantation should be repeated twice. Finally, the suspension obtained from this two-step extraction was then treated together with 30% H_2O_2 to digest the natural organics. The remaining procedure was the same as the water samples.

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