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Synthetic fibers in atmospheric fallout: A source of microplastics in the environment?

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ABSTRACT

Sources, pathways and reservoirs of microplastics, plastic particles smaller than 5 mm, remain poorly documented in an urban context. While some studies pointed out wastewater treatment plants as a potential pathway of microplastics, none have focused on the atmospheric compartment. In this work, the atmospheric fallout of microplastics was investigated in two different urban and sub-urban sites. Microplastics were collected continuously with a stainless steel funnel. Samples were then filtered and observed with a stereomicroscope. Fibers accounted for almost all the microplastics collected. An atmospheric fallout between 2 and 355 particles/m^2/day was highlighted. Registered fluxes were systematically higher at the urban than at the sub-urban site. Chemical characterization allowed to estimate at 29% the proportion of these fibers being all synthetic (made with petrochemicals), or a mixture of natural and synthetic material. Extrapolation using weight and volume estimates of the collected fibers, allowed a rough estimation showing that between 3 and 10 tons of fibers are deposited by atmospheric fallout at the scale of the Parisian agglomeration every year (2500 km^2). These results could serve the scientific community working on the different sources of microplastic in both continental and marine environments.

1. Introduction

Microplastics are a widespread particular contaminant originating from the breakdown of larger plastic debris (secondary) or directly manufactured on a millimetric or submilletric size (primary) (Cole et al., 2011). These plastics have been defined as particles with the largest dimension smaller than 5 mm (Arthur et al., 2008); they cover a continuous spectrum of sizes and shapes including 1D-fibers, 2D-fragments and 3D-spheres.

Given their size, these microparticles can be ingested by a wide range of species, either in marine (Anastasopoulou et al., 2013; Lusher et al., 2013; Thompson et al., 2004) or freshwater environments (Sanchez et al., 2014). These microplastics have negative effects on organisms and the possibility of their translocation, bioaccumulation and trophic accumulation is currently being debated (Wright et al., 2013).

While marine plastic pollution has been well documented, there has been limited focus on the continental contamination (Dris et al., 2015b; Wagner et al., 2014). Moreover, its sources, pathways and reservoirs in urban environments remain largely unknown. It is crucial to gather a better knowledge about these particles in the continental environment as rivers are said to be the main source of marine microplastics (Andrady, 2011). If it is very often cited that 80% of the fibers in the marine environment come from the continent, this estimation is not well documented and demonstrated.

Synthetic fibers are one of the forms in which microplastics can be found. They derive presumably from synthetic clothing or macroplastics. Different pathways are thought to be an important source of fibrous microplastics in the aquatic environment. It has been shown that laundry washing machines discharge large amounts of microplastics into wastewaters (reaching 1900 fibers in one wash (Browne et al., 2011)). During wastewater treatment, synthetic fibers are known to contaminate sewage sludge (Habib et al., 1998; Zubris and Richards, 2005). The sources and fate of microplastics in the various compartments of the urban environment are poorly documented (Dris et al., 2015a); this paper focuses on the atmospheric compartment and investigates the contribution of the atmospheric fallout as a potential vector of plastic pollution.

2. Materials and methods

Total atmospheric fallout was collected on two sampling sites: one in a dense urban environment (48°47′17.8″N, 2°26′36.2″E – Site 1 – Fig. 1) and one in a less dense sub-urban environment. (48°50′27.8″N, 2°35′15.3″E – Site 2 – Fig. 1). Site 1 was monitored over a period of one year (February 19th 2014 to March 12th 2015) and site 2 for a shorter period from October 3rd to 12th March 2015. Site 1 is localized in an area of 7900 inhabitants/km^2 while site 2 is characterized by a surrounding population of 3300 inhabitants/km^2 (Insee — Régions, départements et villes de France, 2011).

The sampling surface was 0.325 m^2 allowing for total atmospheric fallout (dry and wet deposition) to be collected through a stainless steel funnel. A 20 L glass bottle was placed at the bottom of the funnel in an opaque box to collect the water. The samples were collected at

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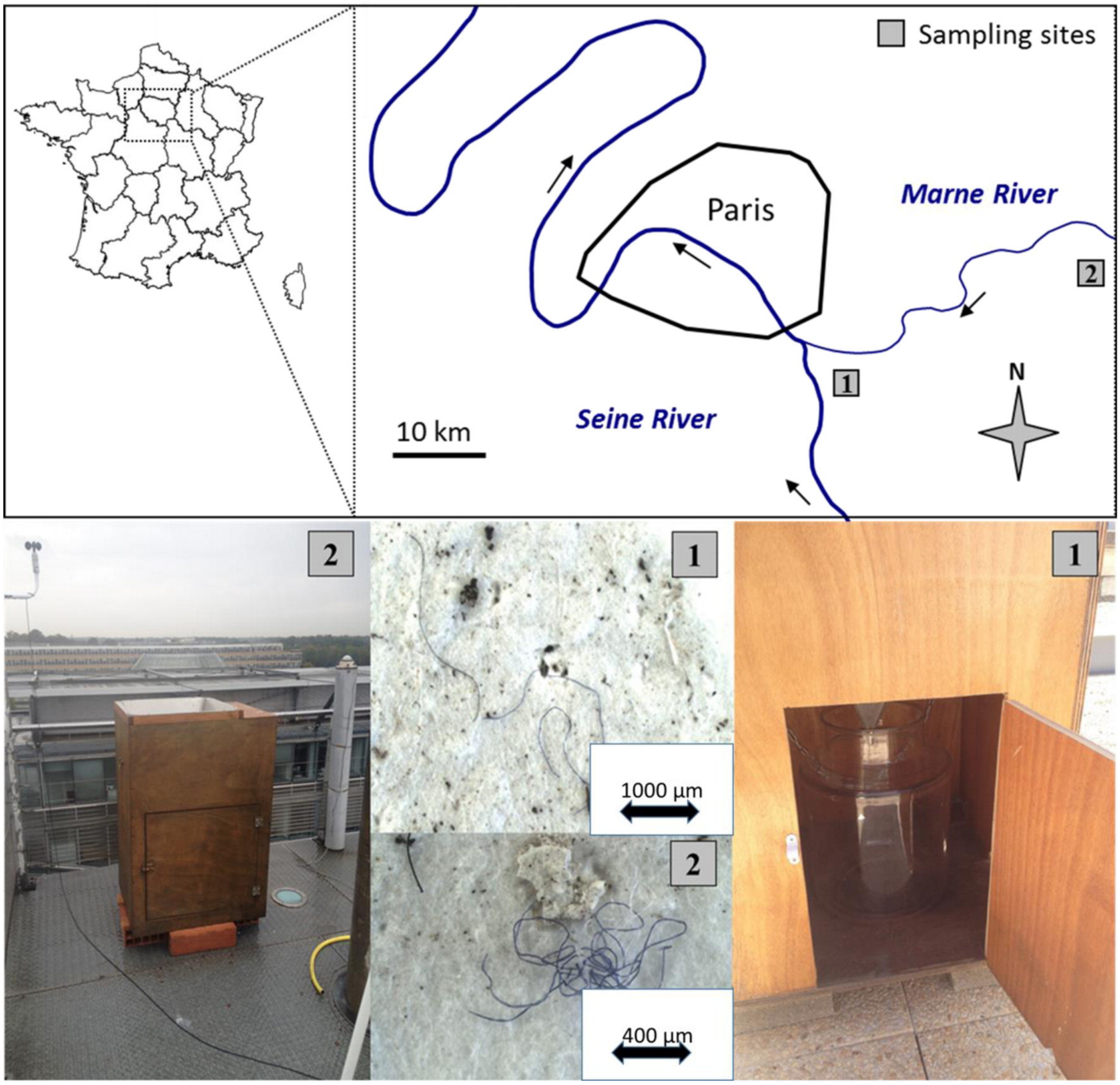

Fig. 1. Localization, sampling device and synthetic fibers for each site.

various frequencies during the monitoring period depending on cumulative rainfall leading to 24 samples at site 1 and 9 at site 2. When both sites were monitored, the collection of samples was carried out the same day for both sites in order to allow comparison. No interruption of the sampling occurred during the whole monitoring period in each site, providing a full view of the annual variability of the atmospheric fallout.

Each time the atmospheric fallout was collected, the funnel was rinsed with 3*1 L of reverse osmosed water in order to recover all particles adhering to the funnel. As commonly done in studies focusing on the pollutant fluxes in atmospheric fallout, preliminary tests demonstrated the efficiency of such rinses. Consecutive rinses with 1 L showed that in the fourth rinse, the number of microplastics is similar to the one in the laboratory blanks. After the rinsing step, samples were immediately covered until the processing step to avoid any contamination. Given the sampling period and the collecting surface area, the atmospheric fallout is expressed as a number of particles per square meter per day. The rainfall was recorded for both sites.

All samples were filtered on quartz fiber GF/A Whatman filters (1.6 μm). To minimize post-sampling contamination from indoor air, samples were always covered. The filters and the vessel were heated to 500 °C prior to their use. All laboratory procedures were performed wearing a cotton laboratory coat. Laboratory blanks were performed to verify that no microplastics are added to the samples during the laboratory procedures. Globally, blank results do not reveal any significant contamination in comparison to the levels found in samples (1 to 2 fibers per filter, representing between 0.5 and 5% of the fibers on the samples).

Filters were observed with a stereomicroscope (Leica MZ12). Previously used criteria were employed in order to identify synthetic fibers (Dris et al., 2015a; Hidalgo-Ruz et al., 2012; Norén, 2007). The accuracy of the method was estimated by comparing the counting of 3 different observers on the same filters. No difference > 5% in the total number of fibers was observed. In 11 of the collected samples, the length of the fibers was measured during the counting (the software "Histolab" coupled with the stereomicroscope). The observation size limit was defined to 50 μm.

Atmospheric fallout in this study is presented as a number of total fibers. Chemical characterization was also performed. A subsample of n = 24 fibers was analyzed with Fourier Transform infrared (FT-IR) micro spectroscopy (Microscope LUMOS FT-IR — Brucker) coupled with an ATR (Attenuated Total Reflectance) accessory in order to characterize the proportion of synthetic and natural fibers and identify the predominant plastic polymers. The fibers were categorized according to the classification proposed by the international organization for standardization (ISO/TR 11827:2012 Textiles — Composition testing — Identification of fibers).