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Synthetic and non-synthetic anthropogenic fibers in a river under the impact of Paris Megacity: Sampling methodological aspects and flux estimations

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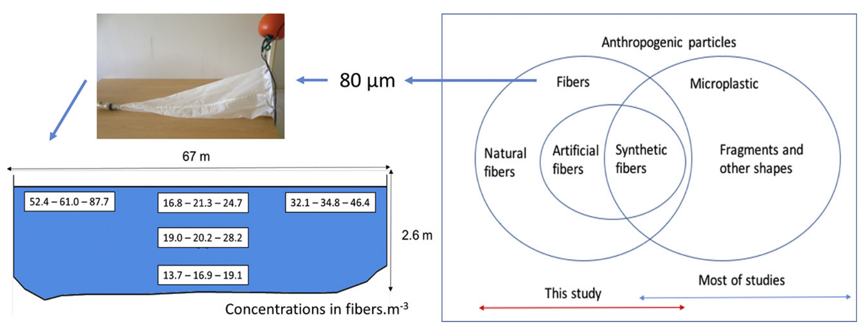
HIGHLIGHTS

- Both synthetic and non-synthetic fibers are encountered in the Seine River.
- A 80 μm mesh size net (vs 330) increases the probability of sampling fibers by 250 times.
- Concentrations of fibers are similar over the river depth.
- Concentration of fibers increase near the banks.
- Fibers don't accumulate in the downstream of Paris in comparison to the upstream.

GRAPHICAL ABSTRACT



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ABSTRACT

Processed fibers are highly present in our daily life and can be either natural, artificial (regenerated cellulose) and synthetic (made with petrochemicals). Their widespread use lead inevitably to a high contamination of environment. Previous studies focus on plastic particles regardless of their type or shape as long as they are comprised between 330 μm and 5 mm. On the contrary, this study focuses exclusively on fibers using a smaller mesh size net (80 μm) to sample freshwater. Moreover, all processed organic fibers are considered, irrespective to their nature. First, the short term temporal variability of the fibers in the environment was assessed. While exposing the sampling net during 1 min a coefficient of variation of approx. 45% (with $n = 6$) was determined. It was of only 26% ($n = 6$) when the exposure was of 3 min. The assessment of the distribution through the section showed a possible difference in concentrations between the middle of the water surface and the river banks which could be attributed to the intense river traffic within the Paris Megacity. The vertical variability seems negligible as turbulence and current conditions homogenize the distribution of the fibers. A monthly monitoring showed concentrations of 100.6 ± 99.9 fibers$\cdot$m^{-3} in the Marne River and of: 48.5 ± 98.5, 27.9 ± 26.3, 27.9 ± 40.3 and 22.1 ± 25.3 fibers$\cdot$m^{-3} from the upstream to downstream points in the Seine River. Once these concentrations are converted into fluxes, it seems that the impact generated by the Paris Megacity cannot be distinguished. Investigations on the role of sedimentation and deposition on the banks are required. This study helped fill some major knowledge gaps regarding the fibers in rivers, their sampling, occurrence, spatial-temporal distribution and fluxes. It is encouraged that future studies include both synthetic and none synthetic fibers.

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1. Introduction

Fibers world production reached 100 million metric tons in 2016 (International Cotton Advisory Committee, 2017) including natural fibers (like cotton) and manmade fibers either artificial (like rayon/viscose) or synthetic (polypropylene, polyamide, etc.). The manmade fraction represents 65 million metric tons for the synthetic fibers which consist of petrochemical polymers, in addition to 6.5 million metric tons of artificial fibers which are regenerated cellulose. Either natural or manmade, processed fibers are present in our daily life and serve for many domestic uses, namely clothes, bed linens, curtains and carpets, chair coverings and upholstery. They are also used in agriculture and fisheries, civil engineering (geotextiles) and more generally in the industry (car, planes, …). As a consequence, to the widespread use of products composed of fibers and their more or less easy abrasion, fibers are now found everywhere in our surrounding environment.

As the production of fibers increases of about 2% per year, fibers are more and more present in the environment. The development of research on microplastics has made it possible to draw attention to the presence of fibers in the environment including marine (Lusher et al., 2015) or continental waters (Mani et al., 2015). It also helped reveal the high amount of fibers that are daily introduced to the environment through wastewater treatment plant effluents (Murphy et al., 2016; Talvitie et al., 2015; Browne et al., 2011). Moreover, they have been detected in indoor air in apartments and offices, as well as in outdoor air (Dris et al., 2017).

Because of their small size the aesthetic nuisance of these fibers is almost inexistent. However, because of their L/D ratio they are easily ingested by organisms (Remy et al., 2015; Lusher et al., 2013; Sanchez et al., 2014). This could cause physical harm most likely related to a disruption of the digestive system (blocking of intestinal tract, false sensation of satiation, etc.) as it was shown for microplastic particles (Farrell and Nelson, 2013; Tourinho et al., 2010; Derraik, 2002; Carr et al., 2012; Cole et al., 2013). It was also shown that the biota ingests various fibers, including both synthetic and non-synthetic ones. The presence of rayon was shown in the organism of fish in the English Channel (Lusher et al., 2013; Lusher et al., 2014). A study also showed the presence of cotton textile fibers in fish from various European seas (Collard et al., 2015). The second category of risks pertains to the fact that these fibers carry a "cocktail of chemicals" they either transport over long distances or release inside an organism after being ingested. Such chemicals are introduced into the plastic polymers during production or may adsorb to them once in the environment (Rochman and Browne, 2013). Fibers made of natural polymers should also be a concern as they are died with carcinogenic substances like the dyes direct red 28 and direct blue 22 (Remy et al., 2015) and contain known harmful additives as flame retardants.

In contrast to the ubiquity of fibers in the environments and to the fact that they get ingested and are potentially harmful, studies focusing on this contamination are very rare. The body of scientific work related to the analyze of anthropogenic particles in environmental waters is mainly oriented towards microplastic particles shaped as fragments, pelleted or spheres. Moreover, while synthetic fibers are often included as a minor sub-category of microplastics, the natural and artificial fibers are (with very few exceptions (Lusher et al., 2013)) automatically dismissed.

Due to these observations, and in relation to the fact that no study focused solely on fibers, it appears necessary to acquire more data in relation to their occurrence in the environment. In contrast with previous studies dealing with microplastics in freshwater, this study focused exclusively in fibers (regardless of the material compositing them) and other shapes of microplastics were not considered. The reasoning behind this decision is twofold: i) fibers are difficult to quantify and require specific methods for sampling and analyzing and ii) the ubiquity of fibers was shown in various studies making it of utmost importance to document this specific contamination. Mineral fibers were excluded. It aimed at i) deriving insights about methodologies for river water sampling regarding fiber quantification and ii) providing sufficient knowledge on fiber levels of contaminations leading to annual fluxes estimations.

The first aim was considered in order to address the representativeness of sampling microplastics in a river, which is an environment with a highly turbulent flow. The short-term temporal variability and the distribution of the fibers through the water section were therefore investigated. For the second aim the variations of the fibers over a period of 19 months in five different sites, both upstream and downstream and urban environment were determined. With this new insight, first attempts to flux estimations of fibers in a river impacted by a megacity were carried out.

2. Material and methods

The Paris Megacity was considered. This megacity is one the world's 40 largest with a population of over 10 million (INSEE, 2013). The Paris agglomeration is crossed by the Seine River; whose catchment drains an area of approximately 32,000 km^2 from the river's headwaters to Paris. This catchment combines intense anthropogenic pressures with a very limited dilution factor due to the low average flow (350 $m^3 \cdot s^{-1}$ in Paris). The transect considered of the Seine River receives two incoming tributaries (Marne and Oise Rivers), the effluents from several wastewater treatment plants (WWTPs) (20–22 $m^3 \cdot s^{-1}$) as well as discharges during wet weather periods (runoff, combined sewer overflows (CSOs), etc.).

2.1. Sampling device

Sampling was performed with a homemade device coupling a plankton net (mesh size: 80 μm–725-cm^2 sampling surface area) with a propeller-type current meter (OTT - C2′10.150′—enabling measurement of water velocity in the range of 0.025 to 5 $m \cdot s^{-1}$). Although plankton nets are typically deployed vertically in freshwater to sample phytoplankton biomasses over a given depth, this net was modified to allow horizontally-flowing water through it. The net was deployed from bridges in order to sample at the middle of the section (points P1 to P5, Fig. 1). The local horizontal flow velocity was measured simultaneously in order to evaluate the sampled volume. A triplicate for velocity measurements was carried out. Clogging during sampling may occur due to suspended matter in the Seine River. Preliminary tests to prevent net clogging were performed. It was shown that the net stopped from sampling when the volume surpassed 8 m^3, in conditions of total suspend solid levels over 10 $mg \cdot L^{-1}$. Quicker clogging is expected with higher suspended solid levels. To ensure the absence of clogging, the sampled volume was always kept largely below the 8 m^3 threshold.

The net was exposed for 1 min as a compromise between increased representativeness, avoidance of clogging and the possibility of sampling between the relatively frequent barge traffic. However, during low flow conditions longer exposure durations have been implemented. The surface layer of the water column was taken into consideration (i.e. a 0.05–0.35 m layer).

Following collection, the net was thoroughly rinsed three times from the outside using river water. Before monitoring, during one sampling, rinsing efficiency was tested. The first three rinses revealed a cumulative number of 61 fibers, while just 2 fibers were found in the fourth rinse.

2.2. Sampling approach

2.2.1. Short scale temporal variability

Two separate campaigns were carried out in order to assess the short scale temporal variability of microplastic concentrations. During the first campaign held on 12th March 2015 at the P1 site (Fig. 1—Marne