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Mountains to the sea: River study of plastic and non-plastic microfiber pollution in the northeast USA

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ABSTRACT

Aquatic environments are sinks for anthropogenic contamination, whether chemical or solid pollutants. Microfibers shed from clothing and other textiles contribute to this problem. These can be plastic or non-plastic origin. Our aim was to investigate the presence and distribution of both types of anthropogenic microfibers along the length of the Hudson River, USA. Surface grab samples were collected and filtered through a 0.45 μm filter paper. Abundance of fibers was determined after subtraction of potential contamination. 233 microfibers were recorded in 142 samples, averaging 0.98 microfibers L^{-1}. Subsequent micro-FTIR showed half of the fibers were plastic while the other half were non-plastic, but of anthropogenic origin. There was no relationship between fiber abundance, wastewater treatment plant location or population density. Extrapolating from this data, and using available hydrographic data, 34.4% of the Hudson River's watershed drainage area contributes an average 300 million anthropogenic microfibers into the Atlantic Ocean per day.

1. Introduction

Within every marine ecosystem and every level of the marine food web; from plankton to predators, there is plastic (Thompson et al., 2004; Law et al., 2010). It has been estimated that approximately eight million metric tons (4.8–12.7) of plastic enters our ocean every year (Jambeck et al., 2015). The longer plastic stays in the marine environment, the more likely it is to break into smaller and smaller pieces due to chemical and mechanical degradation (Browne et al., 2011; Cole et al., 2011). The sources of this pollutant are diverse and include loss from waste management streams, fishing operations, illegal dumping, run-off and natural disasters (Dris et al., 2016).

Pieces of plastic under 5 mm are known as microplastic (Arthur et al., 2009). In the northeast Atlantic, microplastic was found in 94% of all surface samples (Lusher et al., 2014) and a worldwide study found 92% of all surface tows contain microplastics, estimating a global marine surface load of 4.85×10^{12} pieces of microplastic 0.33–4.75 mm in size (Eriksen et al., 2014).

Microplastics can be classified into five different categories due to their shape: Fragments, defined as parts of larger plastics broken into smaller shapes giving jagged edges; Foam, expanded polystyrene, Films, a continuous thin piece of material such as derived from plastic bags or wrappers, Pellets, defined as spherical plastics which are derived from personal care items and pre-production plastics; and Fibers, defined as a threadlike piece of plastic with a length between 100 μm and 5 mm and a width at least 1.5 orders of magnitude shorter (Baldwin et al., 2016; Barrows et al., 2017).

The most abundant type of microplastic found in the environment are fibers. These can come from clothes (Browne et al., 2011, Napper and Thompson, 2016, Pirc et al., 2016) or a direct pathway from clothing to water courses via the atmosphere (Dris et al., 2016; Carr, 2017). In water samples taken in the North East Atlantic, 94% of the samples were found to contain microplastic fibers (Lusher et al., 2014). Naidoo et al. (2015) showed that microfibers were found in between 38 and 66% of estuaries around South Africa. Results on the concentration in these fibers are influenced by the type of sample method with net samples under estimating compared to whole water samples (Barrows et al., 2017), in river samples a range of values from 0.007 (Faure et al., 2015) to 0.00089 (Mani et al., 2015) fibers per liter have been reported (Table 1). Murray and Cowie (2011) found that 62% of the Norway

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Table 1
Abundance of microplastic reported in studies from river environments. "NS" indicates that microfibers were not specified as a counted subset of the microplastics the samples.

Location/type	Abundance microplastics L^{-1}	Sampling method	% microfibers
Switzerland[a]	0.007	300 μm[*]	NS
Los Angeles River[b]	0.00606	333–500 μm[*]	100
San Gabriel River[b]	0.00439	333–500 μm[*]	100
Coyote Creek[b]	0.00434	333–500 μm[*]	100
Rhine River[c]	0.00089	300 μm[*]	NS

[*] Neuston net.
[a] Faure et al. (2015).
[b] Moore et al. (2011).
[c] Mani et al. (2015).

lobster (*Nephrops norvegicus*) collected from the Clyde Sea Area, Scotland, UK contained microfibers. Watts et al. (2015) showed that the ingestion of fibers by the shore crab (*Carcinus maenas*) reduced the amount of food ingested over a 4-week period, this was not compensated by reduced activity which in the long term could induce a starvation effect. Other studies have shown uptake and biological effects on the Freshwater crustacean *Daphnia magna* (Jemec et al., 2016) and the freshwater amphipod *Hyalalella Azteca* (Au et al., 2015).

Not all anthropogenic microfibers are plastic. Clothing and other textiles are made of both plastics including polypropylene, polyester, polyamide, acrylic, polyethylene and non-plastic processed natural materials such as cotton, wool, silk, bamboo, rayon (viscose/regenerated cellulose) (natural) fibers. These non-plastic fibers used in the manufacture of clothing and other textiles are processed, dyed and often coated. Cotton will degrade in the environment more quickly than plastic microfibers; however the degradation process is prolonged when resin is added (Li et al., 2010). Chemicals associated with this processing include flame retardants, Poly Brominated Diphenyl Ethers (PBDEs) and other known carcinogens (Schreder and La Guardia, 2014) making them both an item of health concern and a focus of this study.

Clothing, no matter its composition, breaks down due to: aging and abrasion from wear, and abrasion in the washing machine (Hartline et al., 2016). This abrasion creates microfibers: if the clothing is synthetic this will produce plastic microfibers; if the clothing is non-synthetic this will produce non-plastic microfibers. Washing machines do not have filters capable of capturing such small items. Therefore, microfibers wash out with household greywater, through wastewater treatment plants (WWTPs) and enter public waterways via sewage outfalls (Browne et al., 2011; Mason et al., 2016), or via leech fields in septic systems. When quantifying microfibers in the environment they should be described as anthropogenic microfibers before testing the material to see if they are plastic microfibers or non-plastic microfibers.

Across 17 studied wastewater treatment plants (WWTP), there was an average of 4 million pieces of microplastic, 59% of which was plastic microfiber, leaving each facility per day through the effluent alone (Mason et al., 2016).

Other studies have measured the number of microfibers discharged from WWTPs to range from 0.004 fibers L^{-1} to 160 fibers L^{-1} (HELCOM, 2014; Gasperi et al., 2015), indicating that wash water via WWTP outfall pipes contributes significantly to aquatic microfiber pollution. Effluent is not the only microfiber carrier from WWTPs. Denser fibers such as nylon, polyester, and acrylic can settle out of the wastewater and get caught in the sludge, which is usually repurposed as fertilizer, sending fibers into the environment and waterways via runoff (Habib et al., 1998; Zubris and Richards, 2005). Levels of microfiber pollution are expected to fluctuate seasonally, as household laundry increases as much as 700% in colder months. (Browne et al., 2011).

River systems play a critical role in carrying microfibers to the marine environment (Moore et al., 2011; Lechner and Ramler, 2015; Vermaire et al., 2017). Population centers commonly exist adjacent to bodies of water such as lakes and rivers. WWTPs take advantage of nearby water bodies to receive their effluent. Some microfibers settle into banks and riverbeds, while suspended microfibers are available to be carried downstream to the ocean (Faure et al., 2015; Klein et al., 2015; Mani et al., 2015). Surface monitoring in Switzerland measured an average of 0.007 microplastics L^{-1} (Faure et al., 2015) and in the Rhine River 0.00089 microplastics L^{-1} (Mani et al., 2015). While looking at these numbers, it is important to note that both river studies used 300 μm mesh to filter the water. Subsequent studies have indicated mesh in the 300 μm range is not a fine enough to fully measure the extent of the microplastic/microfiber pollution problem (Kang et al., 2015; Barrows et al., 2017) making the data above a conservative estimate. Investigating river systems and watersheds offers the potential opportunity to learn about specific inputs of microfiber pollution via the presence of WWTPs and population size. Whereas, in contrast, ocean samples reflect the current magnitude of the problem, consisting of microfibers circulating locally and globally, possibly for many years, even decades.

The consequence of microfiber pollution, both plastic and non-plastic to human health is not yet known. However, the negative effect microfibers have on marine life warrants a better understanding of, its sources, and ultimately, preventative and restorative solutions. The overarching purpose of this study is to advance understanding of the presence and concentration of anthropogenic microfibers in an entire watershed, specifically one with diverse population and terrain. The specific study aim is to investigate the presence and distribution of plastic and non-plastic microfibers in the Hudson River, from the headwaters to the sea.

2. Materials and methods

The study area encompasses the Hudson River, New York State, USA; from the headwaters, Lake Tear of the clouds (44.17°N, −73.96°W) to the Atlantic Ocean, Ambrose Light (40.74°N, −73.96°W). The Hudson River basin covers 21,565 km^2.

2.1. Collecting water samples

Abundance of microfibers was determined via the grab sample protocol set out in Barrows et al. (2017). This method was developed and used to ensure uniformity of samples over a variety of sampling platforms (boat, dock, beach, rocks) and reduce contamination. Simply, approximately 3 L of water from the top 8 to 18 cm of the water surface was collected via a triple-rinsed metal bucket and 1 L decanted into a triple-rinsed glass jar of the same volume. Samples of water were collected every 4.3 km (3 miles) over the length of the entire Hudson River. Upper Hudson samples were accessed via car and foot, except for four taken from a whitewater raft (samples 11–14). Lower Hudson samples were accessed from *American Promise*, an 18.3 m sailing research vessel, except for 2 samples (49 and 50) taken via a 3.7 m inflatable dinghy. Sample locations were predetermined with exact sample sites selected by safe access (Upper Hudson) and safe holding position (Lower Hudson). The full list of sample locations can be viewed in SI.1.

2.2. Processing samples

All samples were vacuum filtered through a Whatman 47 mm diameter, 0.45 μm gridded filter paper (Whatman ME 25/21). Flasks and sample bottles stayed capped when not being actively used. The filtrate water was placed in a Fisher 1 L squeeze bottle for rinsing the sample jar and flask during filtration. Once complete, the filters were stored in triple-rinsed (with tap water) metal petri dishes. White cotton lab coats were worn for all processing and laboratory analysis.