Artificial turf fiber pollution in the aquatic environment

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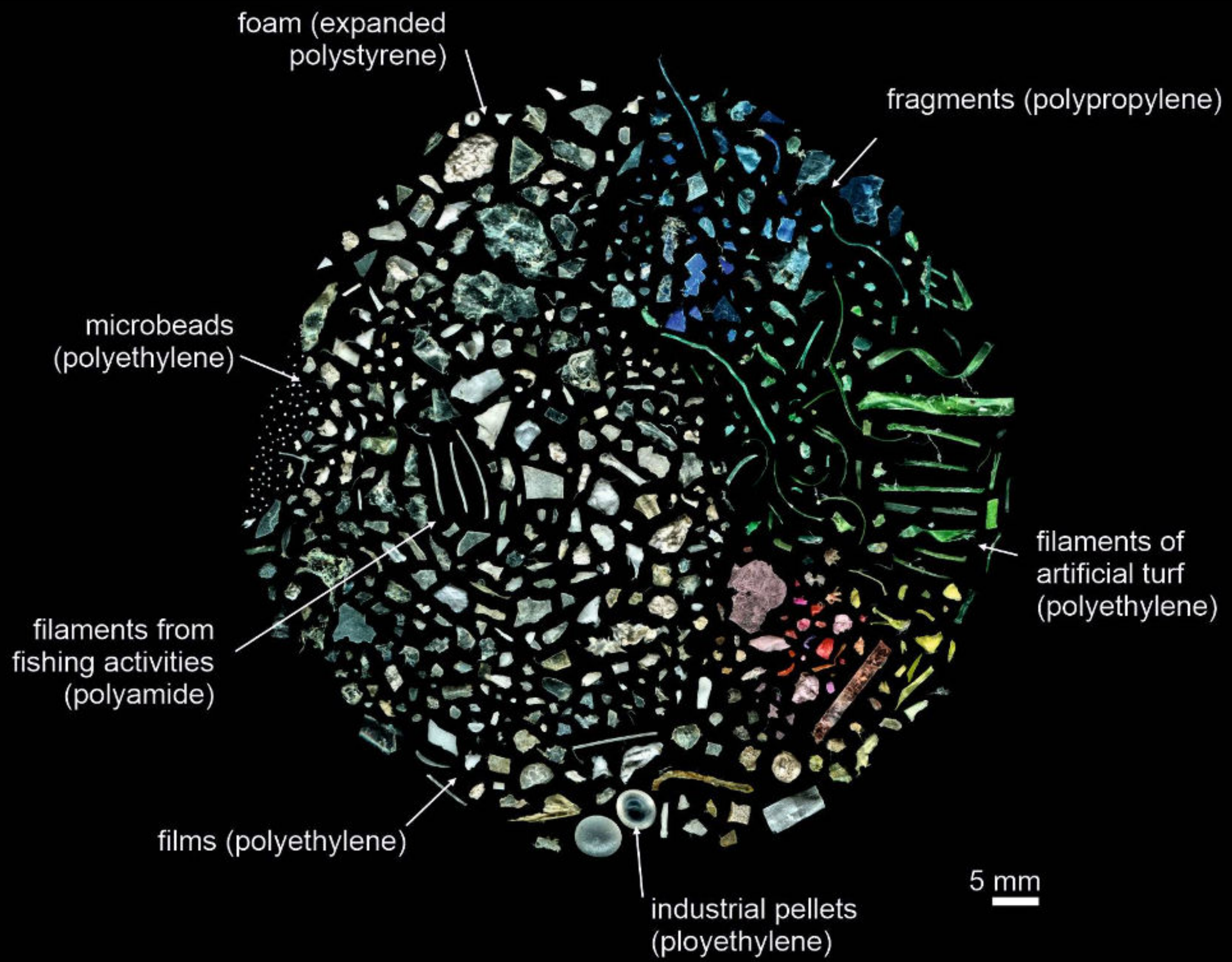
foam (expanded polystyrene)
fragments (polypropylene)
microbeads (polyethylene)
filaments of artificial turf (polyethylene)
filaments from fishing activities (polyamide)
films (polyethylene)
industrial pellets (ployethylene)
5 mm

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The dark side of artificial greening: Plastic turfs as widespread pollutants of aquatic environments☆

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ABSTRACT

Artificial turf (AT) is a surfacing material that simulates natural grass by using synthetic, mainly plastic, fibers in different shapes, sizes and properties. AT has spread beyond sports facilities and today shapes many urban landscapes, from private lawns to rooftops and public venues. Despite concerns regarding the impacts of AT, little is known about the release of AT fibers into natural environment. Here, for the first time, we specifically investigate the presence of AT fibers in river and ocean waters as major conduits and final destination of plastic debris transported by water runoff. Our sampling survey showed that, AT fibers – composed mainly of polyethylene and polypropylene – can constitute over 15% of the mesoplastics and macroplastics content, suggesting that AT fibers may contribute significantly to plastic pollution. Up to 20,000 fibers a day flowed down through the river, and up to 213,200 fibers per km^2 were found floating on the sea surface of nearshore areas. AT, apart from impacting on urban biodiversity, urban runoff, heat island formation, and hazardous chemical leaching, is a major source of plastic pollution to natural aquatic environments.

1. Introduction

Plastics are regarded as a major threat to ecosystems worldwide. Global plastic production reaches peaks of about 450 million metric tons (Mt) annually (Geyer et al., 2017), while estimates of microplastics – plastics smaller than 5 mm in size – in the oceans continue to rise (Isobe et al., 2021). It is estimated that between 19 and 23 Mt are released to aquatic environments each year as of 2016 and will likely double by the end of this decade (Borrelle et al., 2020). Rivers are the dominant pathway for the transport of plastics entering the ocean (González-Fernández et al., 2021), discharging 0.8–2.7 Mt of plastics annually (Lebreton et al., 2017; Meijer et al., 2021). However, reanalysis of plastics entering the sea through rivers suggests that riverine fluxes are up to three orders of magnitude lower, considering that only a small fraction (up to 0.3 Mt) is found floating on the ocean surface globally (Cózar et al., 2014; van Sebille et al., 2015; Weiss et al., 2021). Furthermore, recent studies have suggested that most of the positively buoyant marine plastic debris released from land-based sources is either beached or floating in coastal and especially nearshore areas (de Haan et al., 2022; Lebreton et al., 2019; Onink et al., 2021).

Even under the lower bound scenario of plastic production and waste generation, higher amounts of plastics will likely enter terrestrial and aquatic systems in the following decades, which may lead to many hardly reversible impacts (Lau et al., 2020; MacLeod et al., 2021). Besides the need of curtailing plastic emissions globally, tackling specific sources of plastics will aid in identifying key priorities in order to prevent plastics from entering the natural environments. To date, however, little information is available on the linkage between marine plastic and primary sources, including tire ware, paint coatings, micro-beads, pellets, textile fibers and artificial turf fibers and infill, which might represent up to 31% (2.5 Mt year^{-1}) of the plastics in the ocean (Boucher and Friot, 2017). Most of these plastics are considered microplastics, which can be transported far their source through rivers (Meijer et al., 2021), air (Dris et al., 2016) or urban waterways (Murphy et al., 2016),

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Central questions

Are **artificial turfs (AT)**, an **emerging plastic pollutant**, an important source of plastics in aquatic systems?

What are the **concentrations and properties** of AT in ocean surface waters and rivers

What is the relationship with **rainfall**?

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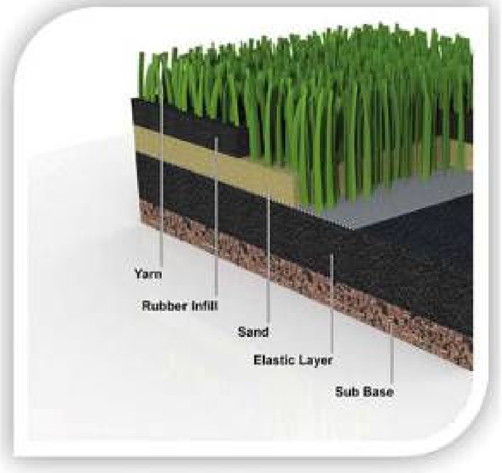
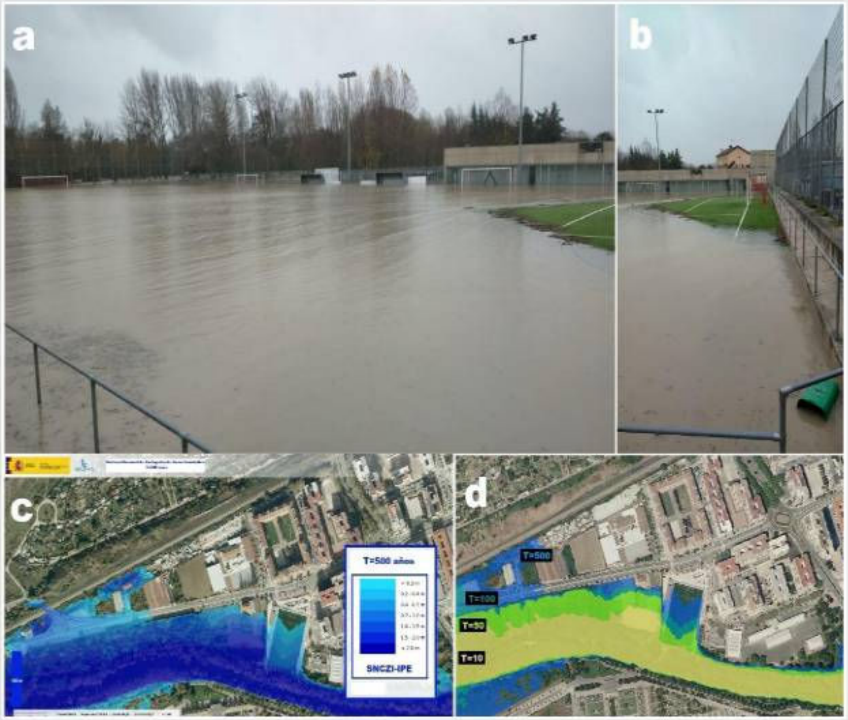
Environmental leaching will likely occur from all materials used in artificial turf surfaces (plastics and added chemicals), not only infill and fibers.

The **environmental fate** and impacts will largely depend on the chemical and physical properties of the plastic (e.g. density, shape, length, etc.)

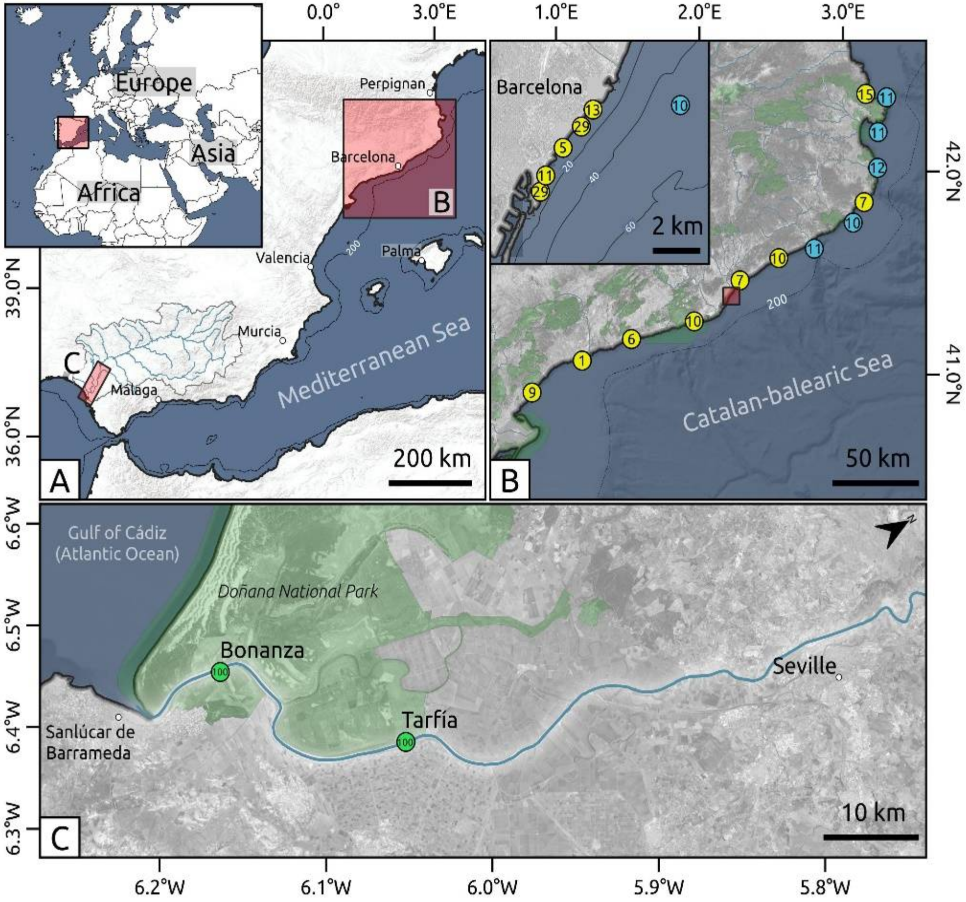


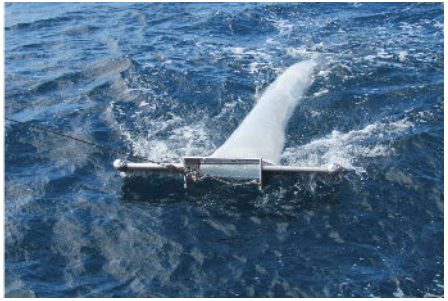
Olshammar et al. (2021)

Grass fibre	• PE, PP, PET, PA6
Granulate infill	• None • SBR, EPDM, TPE, sand, cork, others
Backing	• PUR, Latex, PE, PP, PET, PA6
Shock layer	• SBR, PUR, E-PP
Substrate	• Crushed gravel and stone flour • Drain sheet (PP, EPDM)



Aretxabala (2022)





2014 – 2015 – 2016 – 2018 – 2019 – 2020 – 2021

Manta trawl, Paddle trawl, and river net

200 – 1000 µm

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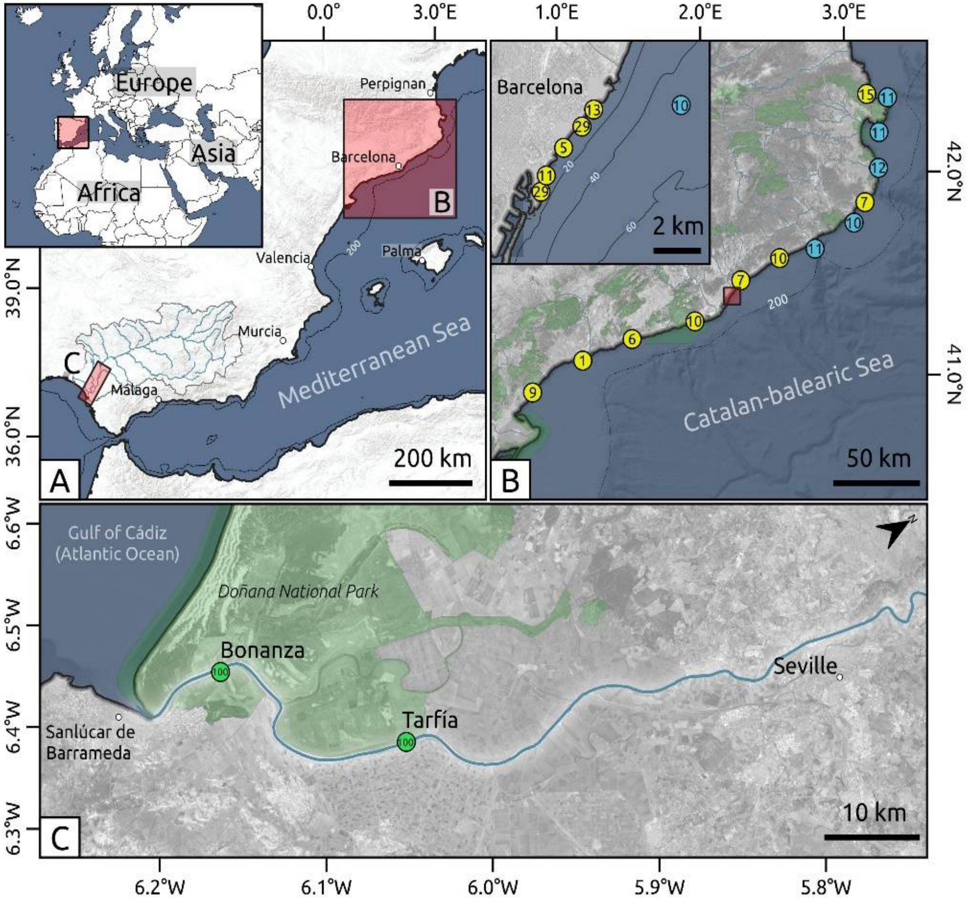
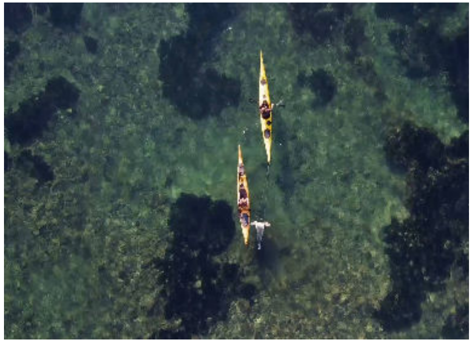
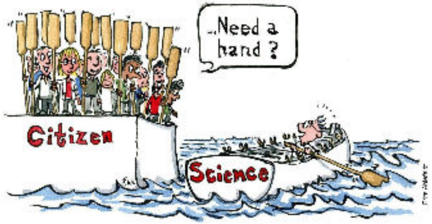


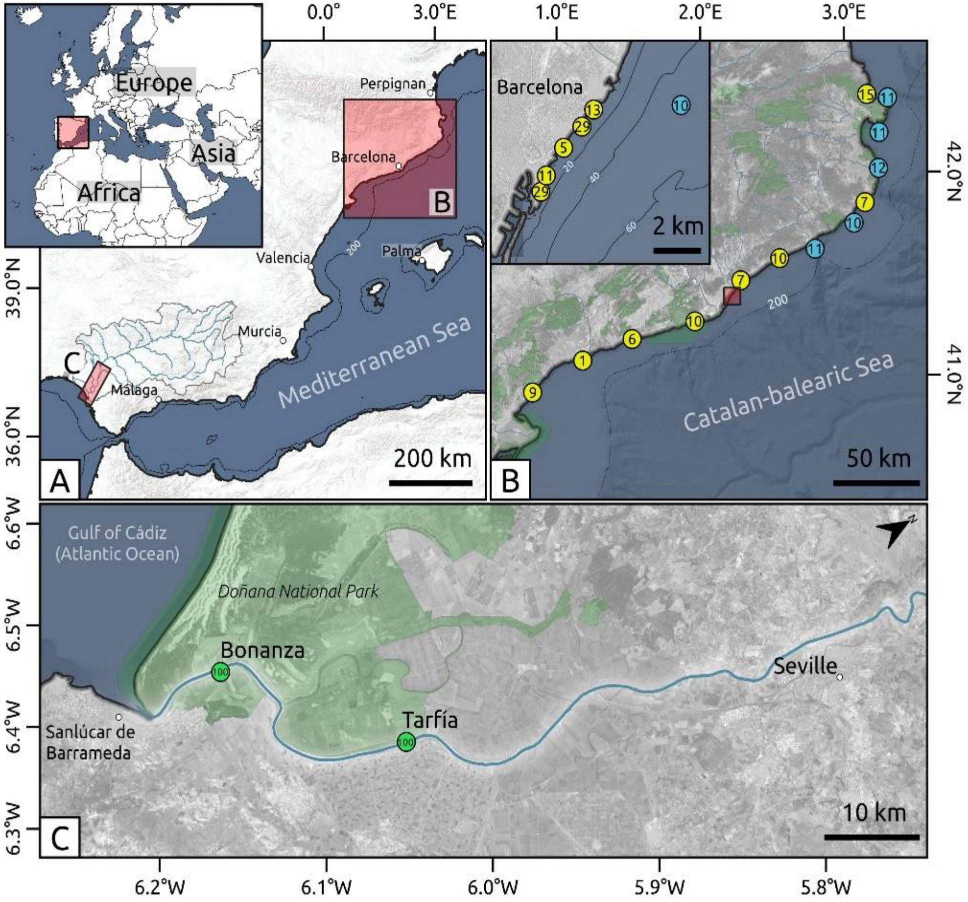




2014 – 2015 – 2016 – 2018 – 2019 – 2020 – 2021

Manta trawl, **Paddle trawl**, and river net

200 – 1000 µm



2014 — 2015 — 2016 — 2018 — 2019 — 2020 — 2021

Manta trawl, Paddle trawl, and **river net**

200 – 1000 µm

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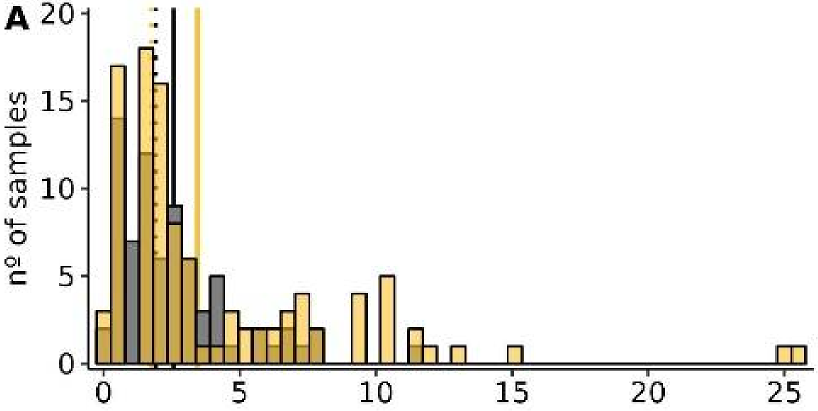
Proportions relative to plastic loads

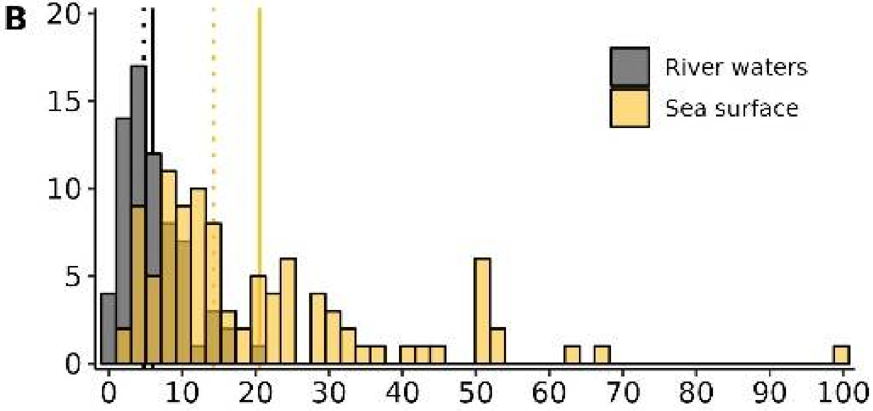
AT fibers found in **> 50% of samples** (N_{total} = 417)

% AT fibers vs. all plastics



AT represented 1.2% (sea surface) and 0.3% (river waters) of all plastics (N_{total}= 88,502)

% AT fibers vs. > 5mm plastics

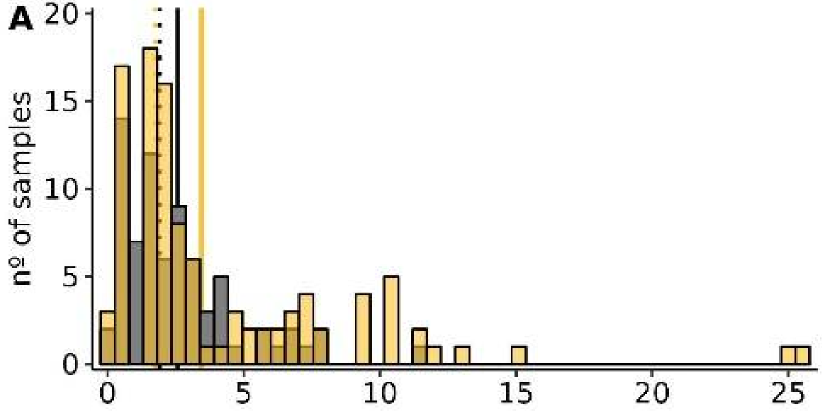


Plastics > 5 mm in length: **12.2% sea surface (15.6% in nearshore) and 2.4% in river waters**

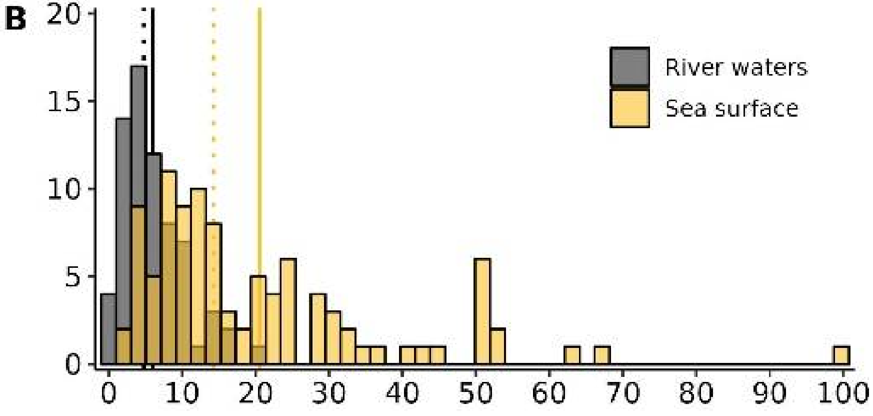
Proportions relative to plastic loads

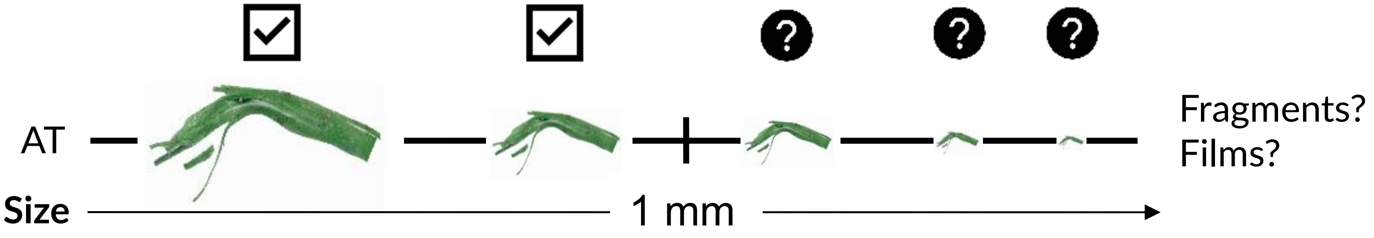
AT fibers found in **> 50% of samples** (N_{total} = 417)

% AT fibers vs. all plastics



% AT fibers vs. > 5mm plastics



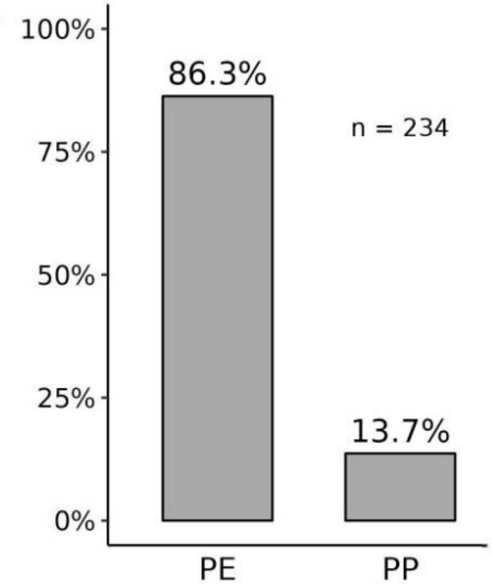


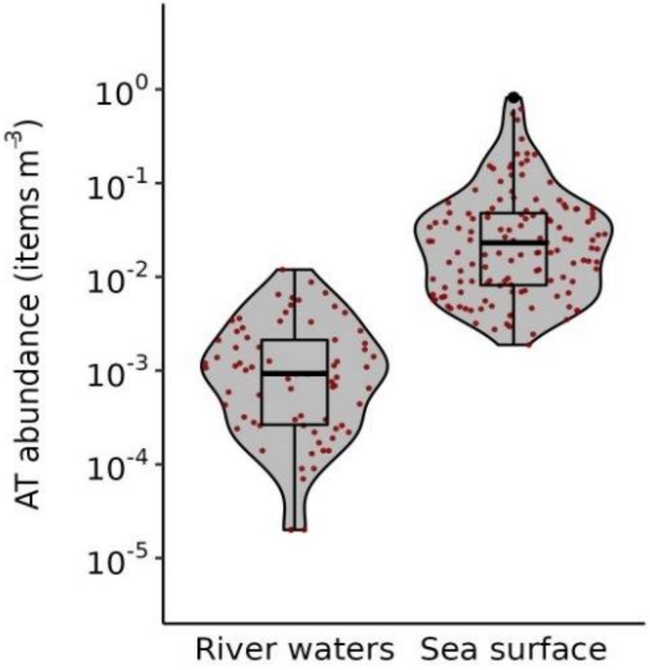
AT fiber composition, color, and concentrations

Mostly composed of **polyethylene** (PE) and **polypropylene** (PP)

Green (82%), yellow (13%), brown (4%), and gray (1%)

[AT] **x50** in surface waters





Sea surface:

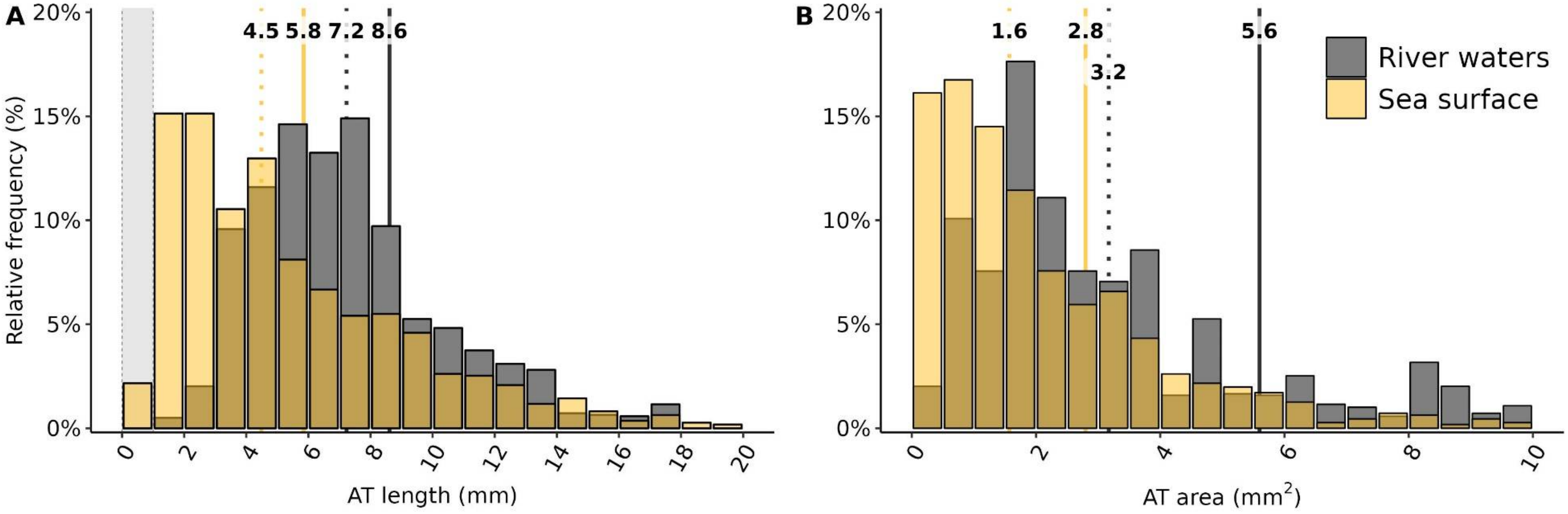
- 0.03 items m^{-3} (0 – 0.82 items m^{-3})
- 0.09 items m^{-2} (0 – 0.21 items m^{-2})

River waters:

- 0.0006 items m^{-3} (0 – 0.01 items m^{-3})

Lower retention vs. long-term accumulation

AT fiber size



Significantly **longer and larger in samples from river waters** (mean: 8.6 mm and 5.6 mm^2; range: 1.8–58.8 mm and 0.3–78.1 mm^2) **than from the sea surface** (mean: 5.8 mm and 2.8 mm^2; range: 0.3–61.7 mm and 0.1–60.6 mm^2)

Residence times of AT and proximity to sources

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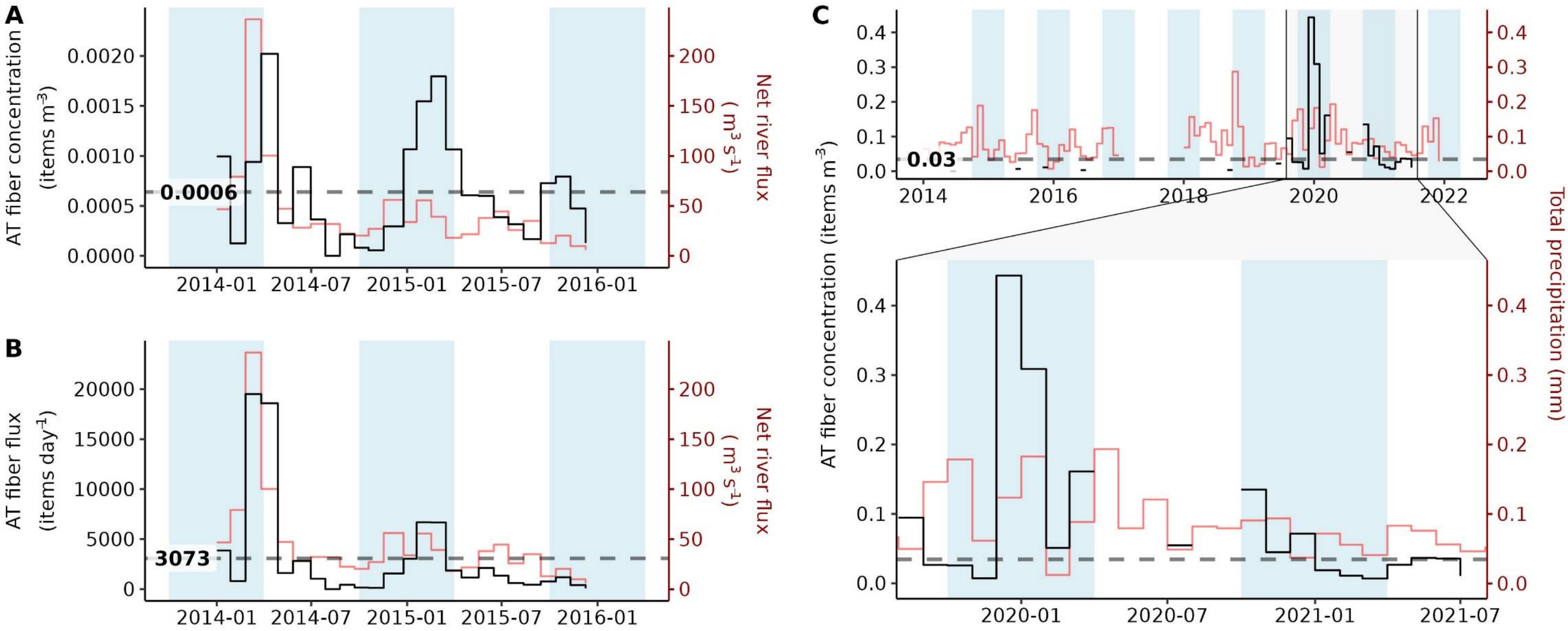

Average river flux: 3,073 fibers day^{-1} (**up to 20,000 fibers day^{-1}** or **1.1 million fibers year^{-1}**)
0.0025 kg day^{-1} (**up to 0.014 kg day^{-1}** or **5.1 kg year^{-1}**)

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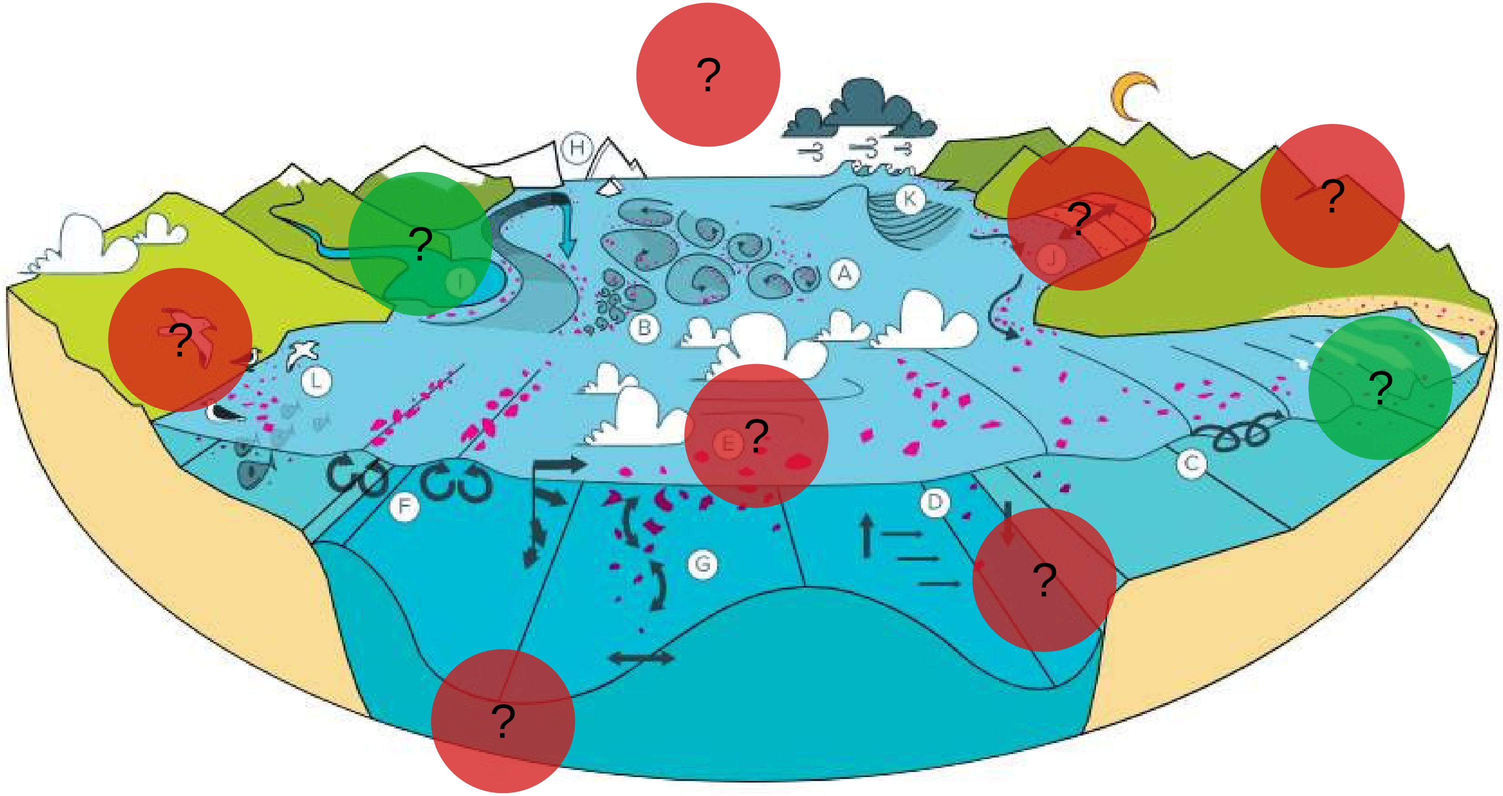

River (other river systems?)

Coastal (other coastal areas, mangroves, etc.)

Beaches?

Offshore?

Water column?

Sediments (river, coastal, deep-sea sediments?)

Ingestion by organisms? Impacts?

Atmosphere? (e.g. urban dust)

Terrestrial?

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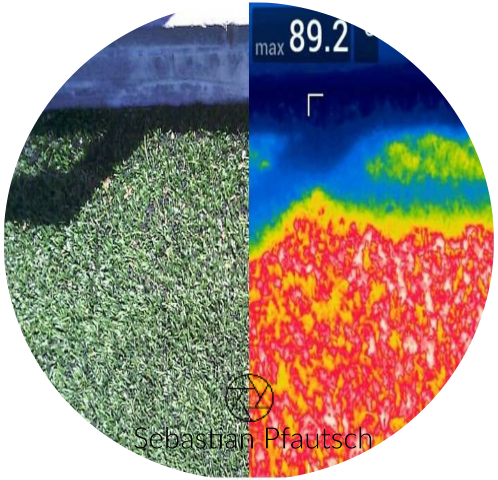
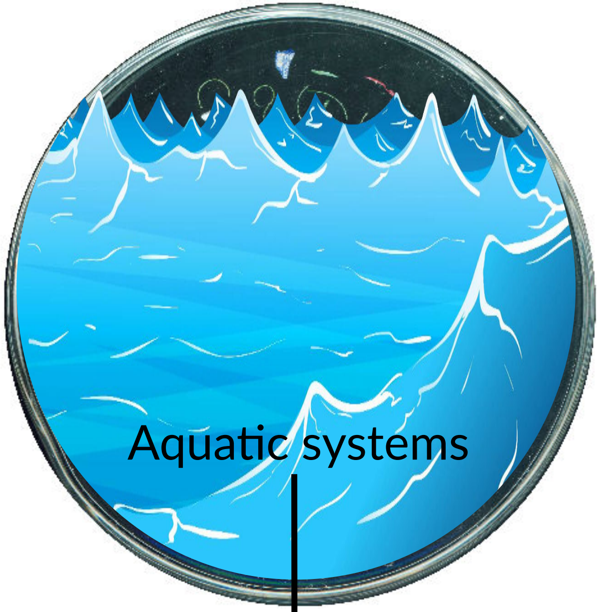
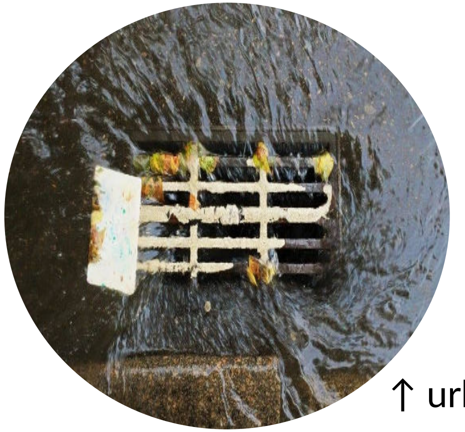
Urban biodiversity



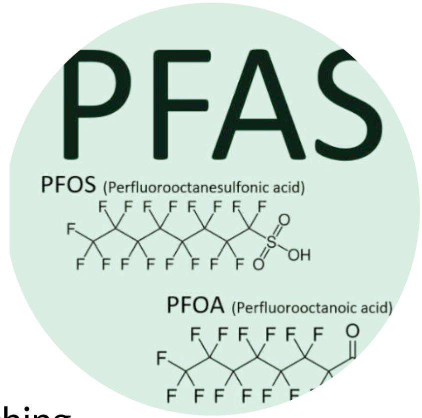
Heat island formation



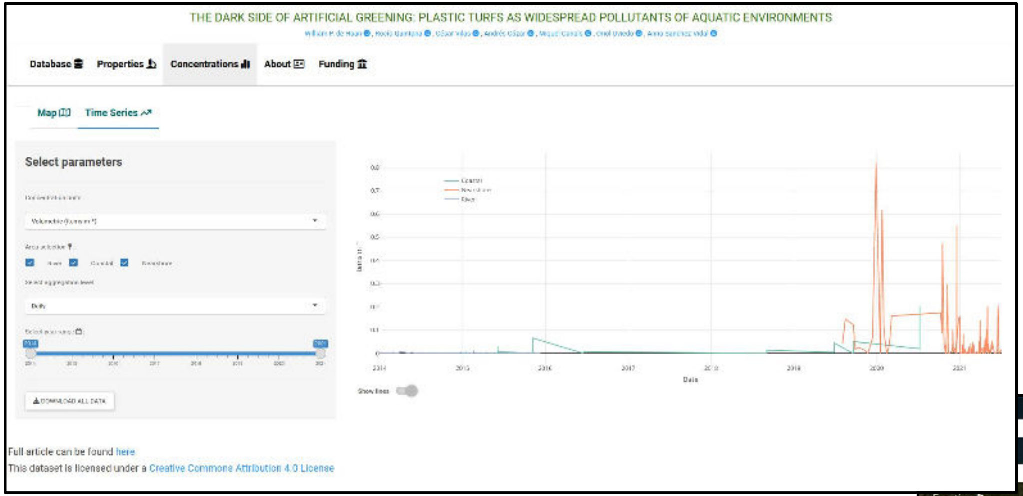
Monitoring



↑ urban runoff



Chemical leaching



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