All that glitters is not plastic: the case of open-ocean fibres

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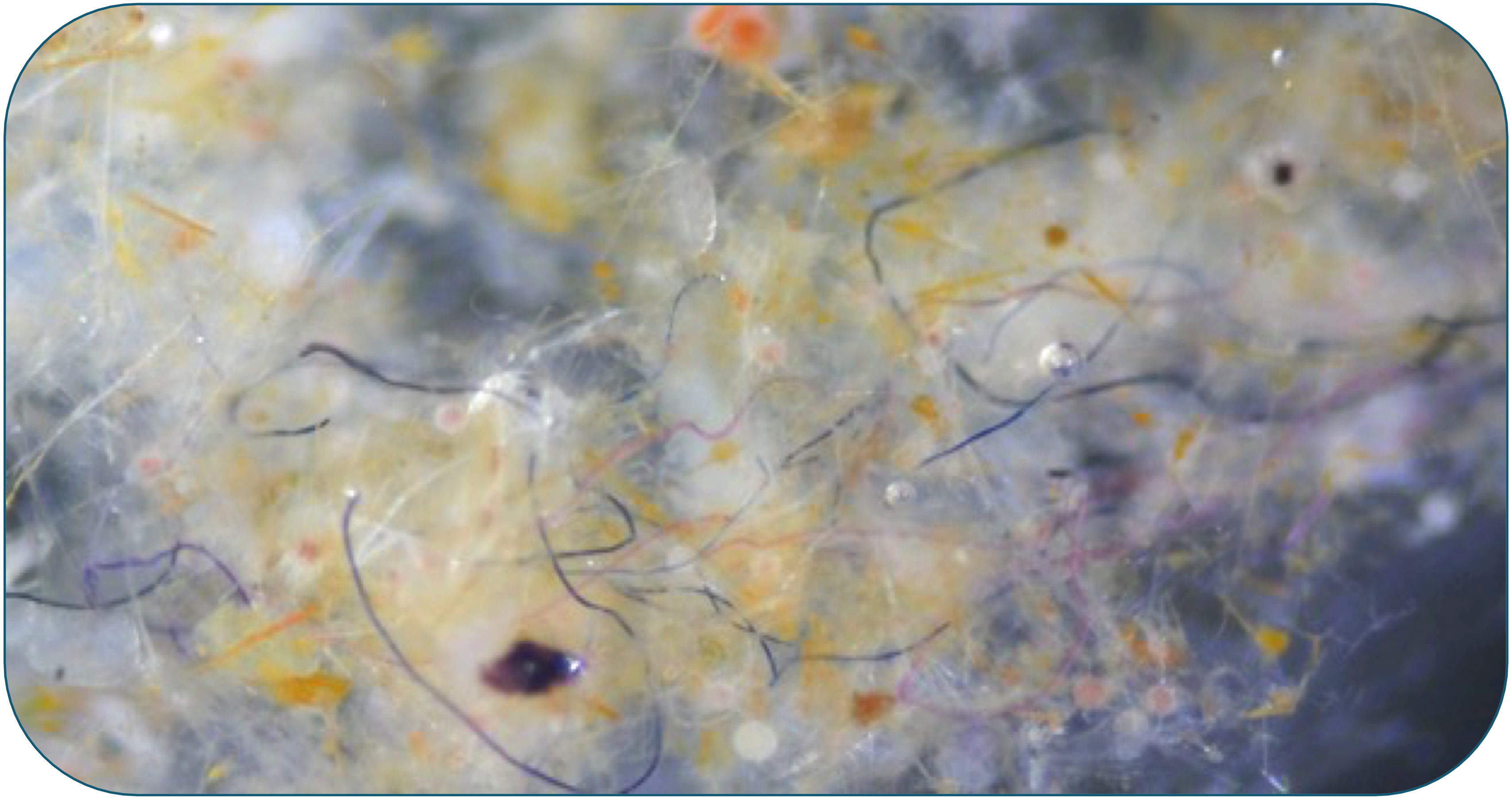
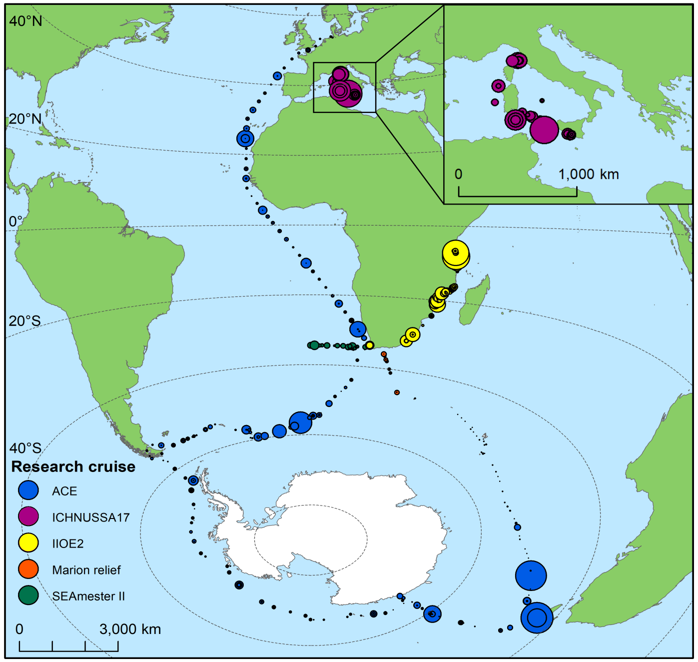


WATER SAMPLING

- 5 research cruises between January and November 2017.
- 916 seawater samples collected at 617 locations (2/3 replicates per station).
- 710 bulk-water samples collected with a 10-liter stainless steel bucket.
- 206 paired sub-surface samples collected from the ship's underway pump.
- Sampling was made outside of the bow wave, while the ship was slowly moving forward.
- Water was poured into 10-liters pre-washed containers for on-board gravity filtration.
- Vacuum or gravity-filtered through 20-63 µm mesh filters (Ø55 mm) and stored in petri-pads at -5°C.



CONTAMINATION CONTROL

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- Bucket always rinsed three-times in seawater before sampling.
- All filters, lab-ware and sampling equipment triple rinsed with MilliQ water prior to use.
- Samples and sampling equipment kept covered at all times during processing

AERIAL CONTROLS (n=125)

Clean filters exposed to the open-air during sampling and laboratory procedures.

2.0 ± 3.2 fibres·h^{-1} (median: 1.0)

Low airborne contamination levels during sampling (i.e. ~0.2-0.3 fibres/sample, given that processing took 5-10 minutes).

PROCEDURAL BLANKS (n=22)

10 liters of Milli-Q filtered on-board using the same sampling equipment.

1.1 ± 1.1 fibres·l^{-1} (median: 0.65)

Greater contamination risk, but still significantly lower than environmental concentrations ($p < 0.0005$).

All samples were conservatively reduced by 1.0 fibres·l^{-1}

LABORATORY ANALYSIS

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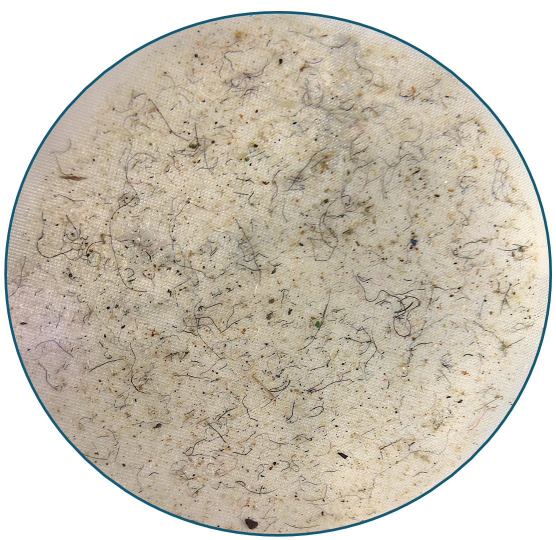
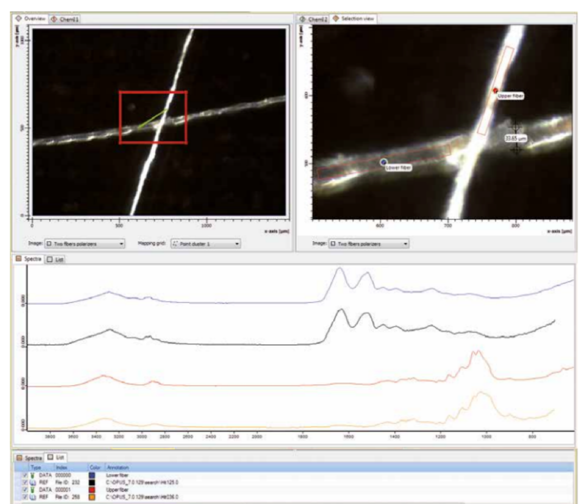
- Counting and sorting at the stereomicroscope by the same individual according to standard criteria.
- Raw fiber concentrations computed for all samples and expressed as fibres·l^{-1}
- A random subset of 2134 fibres (i.e. ~10 fibres/sample) extracted for µFTIR analysis (Bruker LUMOS in ATR-mode).
- Fiber length and diameter measured to the nearest 1 µm from the digital images collected by the instrument.
- Polymer ID with commercial and custom libraries augmented with spectra of common fabrics, clothing and textiles.
- Only matches > 75-80% with reference spectra were accepted as verified polymers.
- Fibres were classified as: **Synthetic** (polyester, acrylic, polyamides, aramids, polypropylene), **Animal** (wool, silk) or **Cellulosics** both natural (cotton, linen, jute, kenaf, hemp, flax, sisal) and man-made (rayon/viscose, acetate).

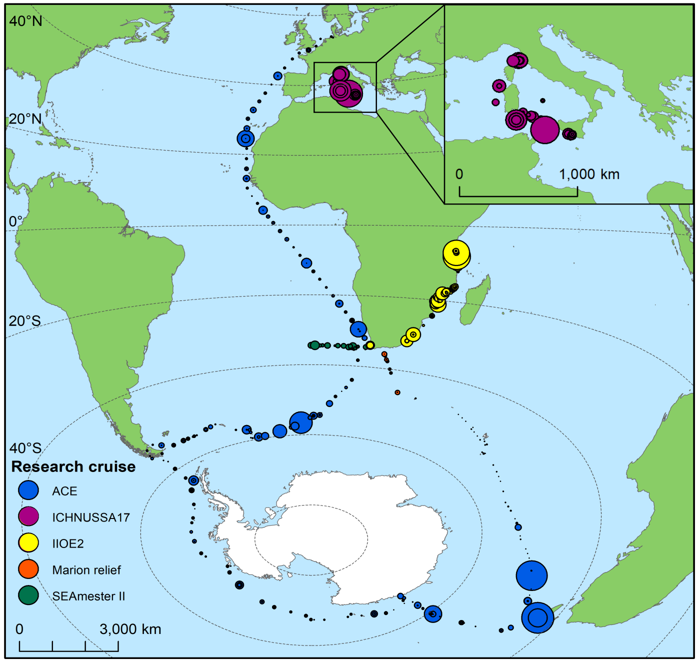


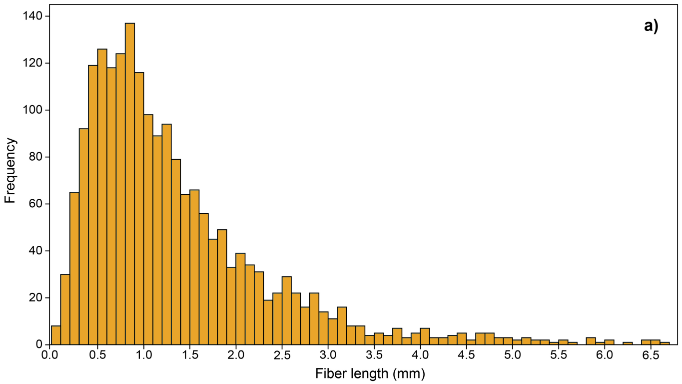


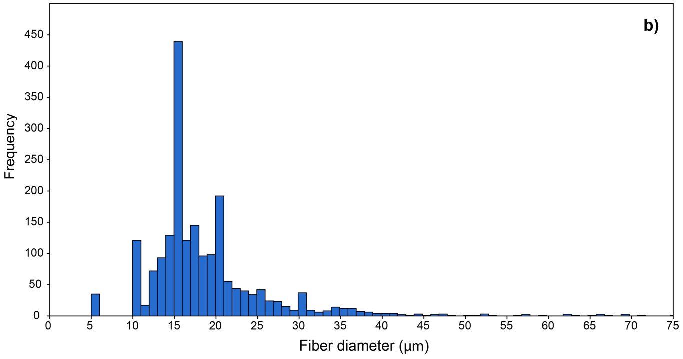
RESULTS

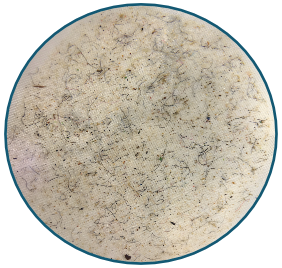
ABUNDANCE AND DISTRIBUTION

- 23,593 fibres counted (median 18 fibres/sample, Q_1-Q_3: 10-31)
- Fibres found in 99.7% of samples (range: 0.02-25.8 fibres·l^{-1})
- Median concentration: **1.7 fibres·l^{-1}** (uncorrected)
- No clear trend in relation to distance with land









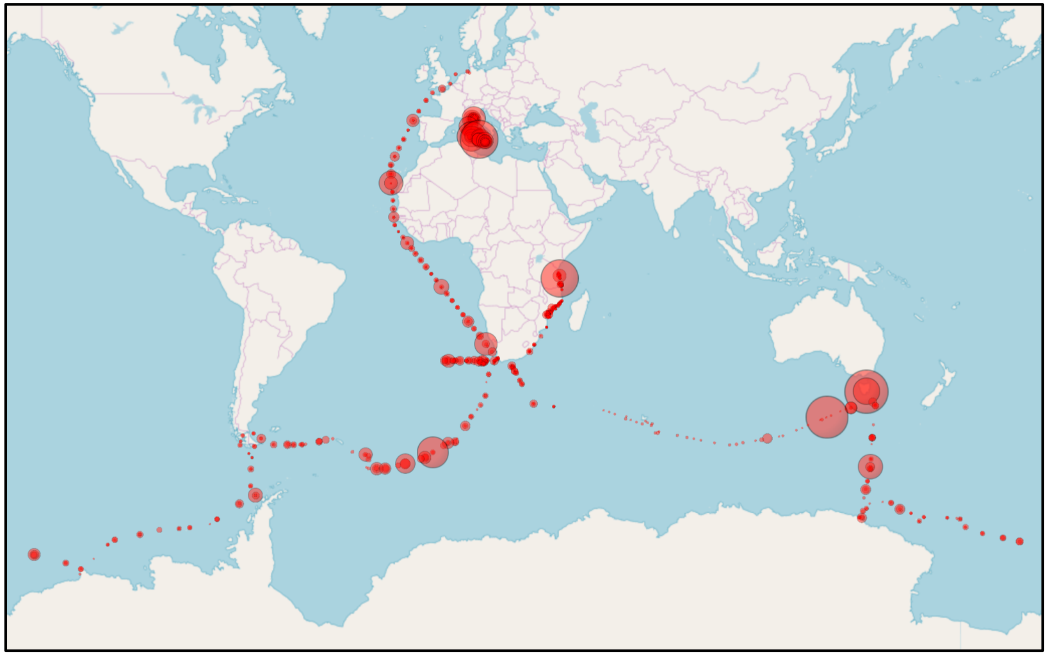
Length: median 1.07 mm (range: 0.09–27.06 mm)
Only 10 fibers longer than 10 mm and only 3 >15 mm.

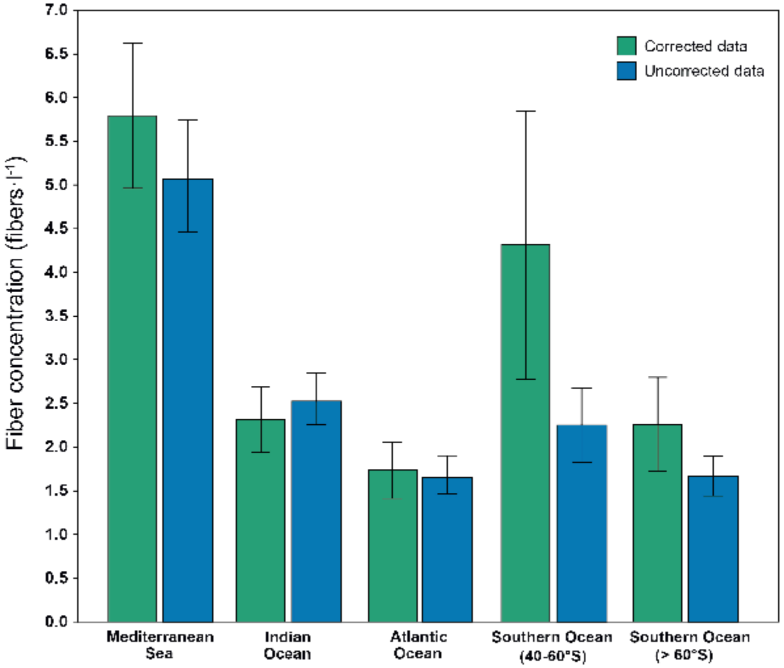
Diameter: median 16.7 µm (Q_1-Q_3: 15.0-20.4 µm; range: 5-239 µm)

Colors: Most fibers were dark/black (57.1%) or light/grey (24.2%), followed by blue (10.1%), red/orange (5.2%), yellow/amber (2.9%) and green (0.4%).

RESULTS

- **Fiber concentration was not homogenous across ocean basins**
- High concentrations were found in the Mediterranean Sea and in the Southern Ocean.
- Fiber concentrations tended to increase from north to south (negative correlation with latitude).
- Using the 25-75% CI of our dataset, we estimate a **global load of 0.2–1.1 x 10^{18} floating fibers**.
- In terms of weight, the total amount of textile fibers (**86–383 thousand tonnes**) is in the same order of magnitude of floating plastics (**93–236 thousand tonnes;** van Sebille et al. 2016).





RESULTS

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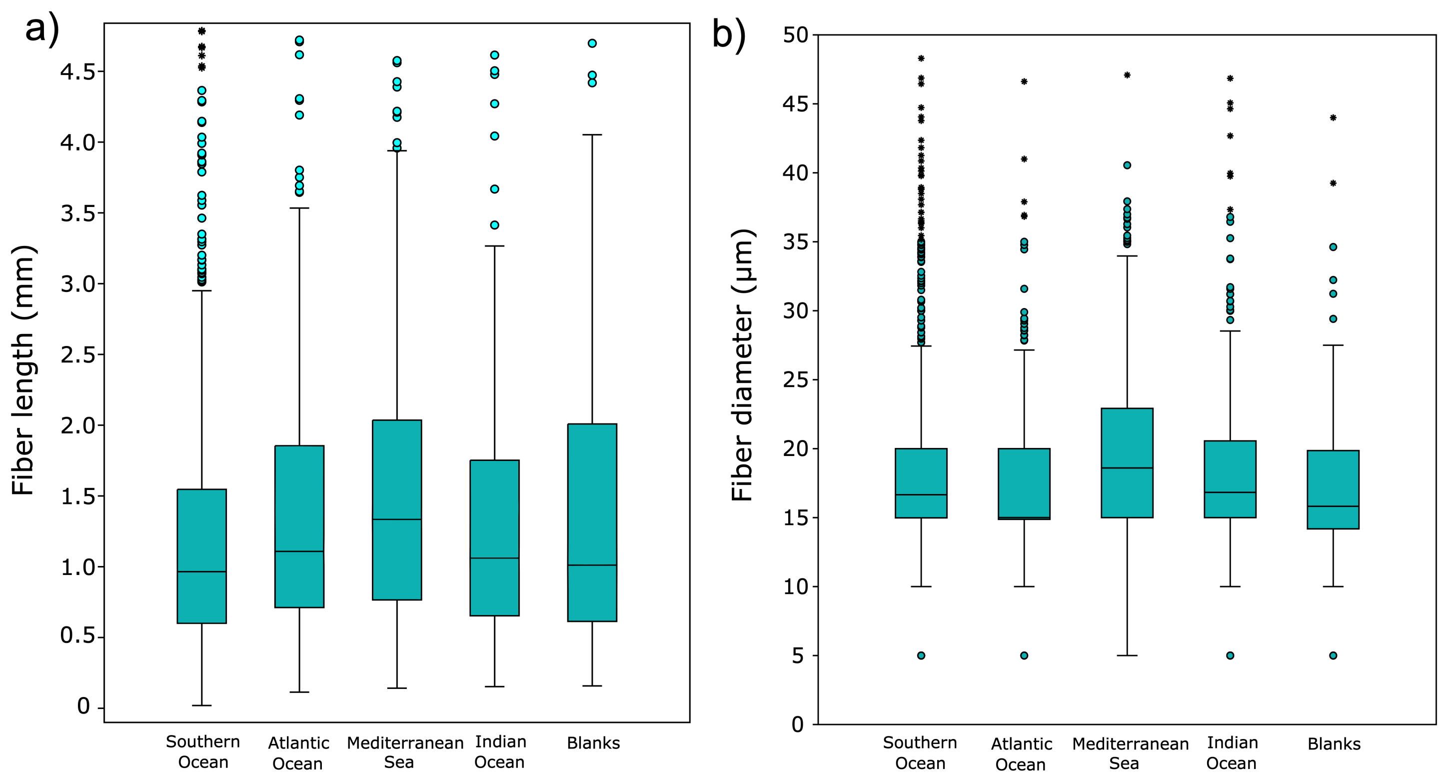
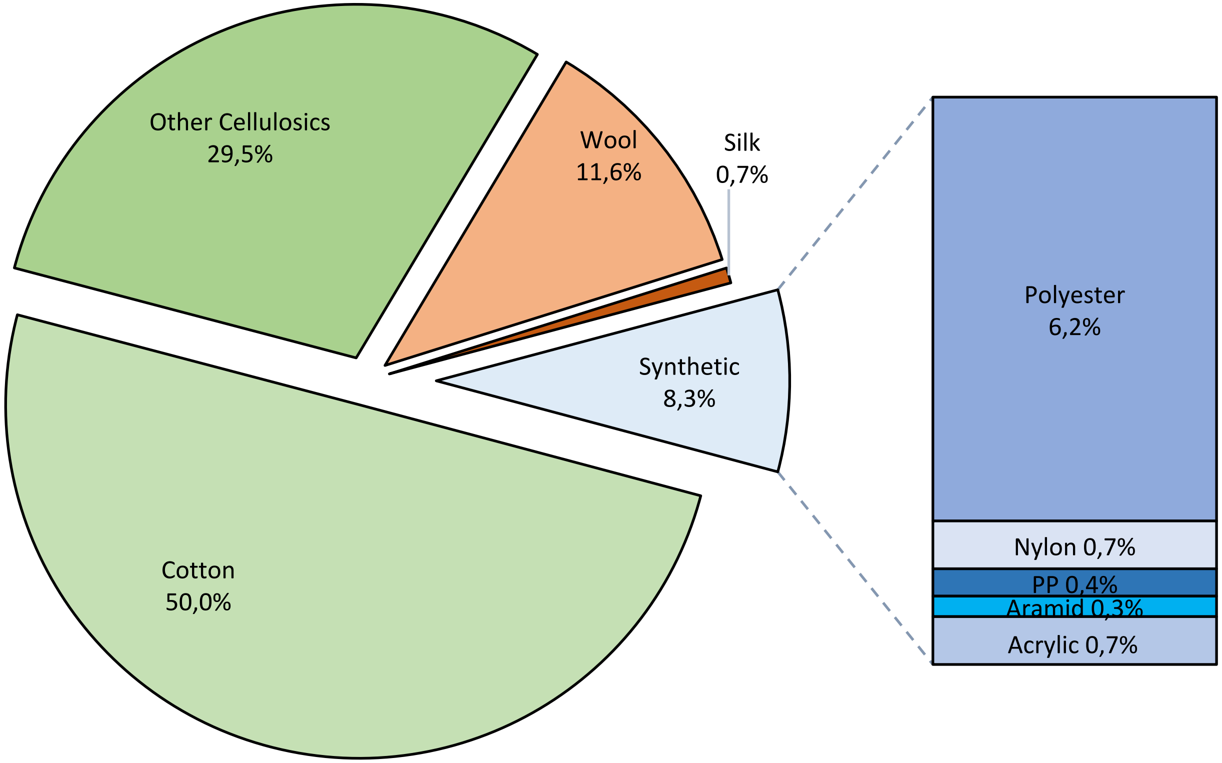
- Significant differences were found also in fiber lengths and diameters among ocean basins.
- Fibers from the Mediterranean were significantly longer and thicker than those found in other basins.
- Fibers from the Southern Ocean were significantly shorter than all other basins.
- Fibers from the Indian and the Atlantic Ocean were of intermediate length



The fibers extracted from procedural blanks (n=161) were significantly thinner, but not shorter than those extracted from seawater samples.

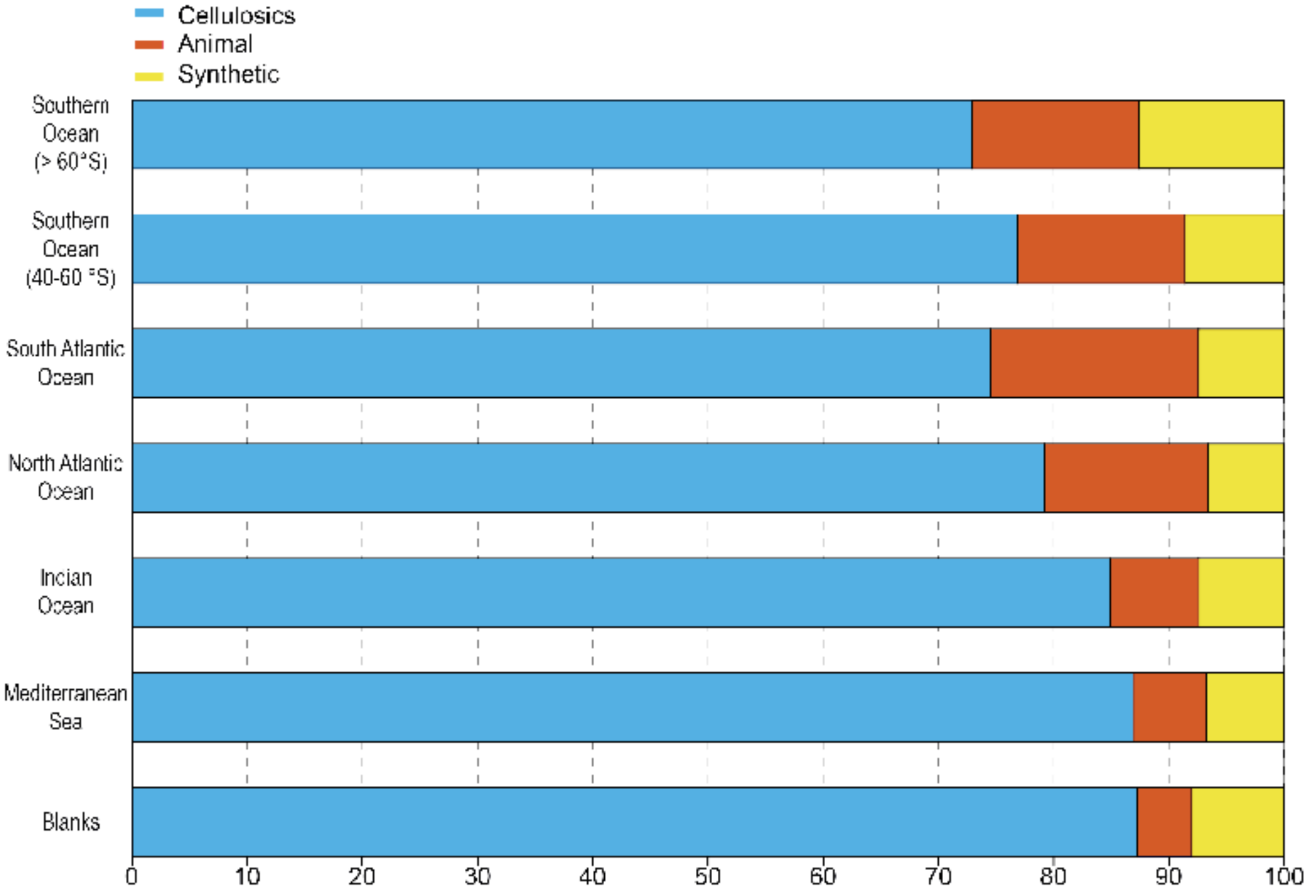
µFTIR ANALYSIS



- **91.8% of all analyzed fibres (n = 1984) were natural fibres of animal or plant origin.**
- Most fibres are non-synthetic: cotton 50%, wool 11.6% or other cellulosics 29.5%.
- Only 8.2% synthetic, with polyester the most abundant (6.2%), followed by nylon (0.7%), acrylic (0.7%), polypropylene (0.4%) and aramid fibers (0.3%).

µFTIR ANALYSIS

- The composition of fibers was not homogenous across ocean basins, but the general trend remains constant (cellulosics >70-80% in all oceanic basins).
- The proportion of synthetic fibers increased at higher latitudes from 6.8% in the Med to 12.6% in Antarctic waters south of 60°S (similar pattern for wool fibres).



Fibers extracted from the blanks (n=150) were characterized by a higher proportion of cellulosics (87.3%) and a shortage of wool (4.7%) if compared to seawater samples.

OUTLOOK

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- ✓ Most fibres at the sea surface are not plastic, but dyed cellulosics (both natural and man-made).
- ✓ The assumption that most if not all fibers are synthetic has led to significant overestimates of the abundance of microplastics in natural ecosystems (fibers often account for 80-90% of all particle counts).
- ✓ Synthetic fibres dominate global textile production (62%), but accounts for only 8% in our samples.
- ✓ Cellulosic and animal fibres account for 80% and 12% of our samples, despite comprising only 36% and 2% of global production. This contrasts with the pattern of plastic litter (PE and PP most common).
- ✓ This discrepancy might be explained by:
  1. Higher shedding rates of natural fabrics compared to synthetic textiles.
  2. The historical dominance of plant and animal fiber use in textiles.
  3. Lower-than expected degradation rates of natural fibres at sea (role of dyes, additives?).
- ✓ All polymers found in our study have densities greater than seawater and should sink.
- ✓ Their widespread occurrence in surface waters could be explained by constant atmospheric deposition coupled to retention within the surface microlayer and/or turbulence and re-suspension processes
- ✓ Research on the fate and impacts of textile fibers is often unbalanced in favor of plastic polymers.
- ✓ More information is needed on the degradation of natural vs synthetic fibers as well as a better understanding of ecological impacts and biodegradation rates in a range of environmental conditions.

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