ENVIRONMENTAL RESEARCH
COMMUNICATIONS

INCLUSIVE PUBLISHING
TRUSTED SCIENCE

Part of the
ENVIRONMENTAL RESEARCH
SERIES

PURPOSE-LED
PUBLISHING™

PERSPECTIVE • **OPEN ACCESS**

Eco-friendly or eco-threat? The environmental risks of natural and semi-synthetic fibers

To cite this article: Daniel J Jolly *et al* 2025 *Environ. Res. Commun.* **7** 052502

Environmental Research Communications

PERSPECTIVE

Eco-friendly or eco-threat? The environmental risks of natural and semi-synthetic fibers

Daniel J Jolly[1,*], **Elisabeth Allen**[2], **Brigitta Olah-Kovacs**[3], **Hayley McIlwraith**[1,4], **Richard J Warren**[1], **Charlotte Woodhouse**[4,5], **Maria Staines**[1], **Amy C M Wright**[3], **Bas Boots**[3], **Trevor J Tolhurst**[1] and **Dannielle S Green**[3,*]

[1] School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ, United Kingdom
[2] Department of Materials, University of Manchester, Oxford Road, Manchester, M13 9PL, United Kingdom
[3] Applied Ecology Research Group, School of Life Sciences, Faculty of Science and Engineering, Anglia Ruskin University, Cambridge, CB1 1PT, United Kingdom
[4] Marine Ecology and Biodiversity, Plymouth Marine Laboratory, Plymouth, PL1 3DH, United Kingdom
[5] University of Exeter, Geoffrey Pope Building, Stocker Road, Exeter, EX4 4QD, United Kingdom
[*] Authors to whom any correspondence should be addressed.

E-mail: danieljolly904@gmail.com **and** Dannielle.Green@aru.ac.uk

Keywords: eco-friendly, eco-threat, natural, fibers, pollution, microplastic

PUBLISHED
23 May 2025

Abstract

Microplastic synthetic fibre pollution from textile products has been a key focus of environmental research since the mid 2000s, with numerous investigations establishing their ubiquity in natural systems and the ecological threats they pose. Natural and semi-synthetic fibres, however, have been largely ignored due to assumptions of their negligible environmental impact and rapid degradation due to their natural material sources. There is, however, growing evidence of widespread pollution by natural and semi-synthetic microfibres, especially in aquatic environments, at levels equivalent to or exceeding those observed for synthetic microfibres. Difficulties in reliable identification and detection of microfibres in environmental samples has limited our knowledge and understanding of their presence, abundance and impacts; yet investigations into the ecological threats posed by these fibres suggest similar or even greater negative impacts on organisms than their synthetic counterparts. Here we briefly summarise the state of this emerging field and stress the importance for future research to focus on quantifying and assessing the threats posed by natural and semi-synthetic microfibre pollution alongside those from synthetic fibres.

An overlooked pollutant

Synthetic fibres (e.g., polyesters, polyamides) were first introduced in the 1930s and have since been widely used in the textile industry. Scientific research has established the widespread pollution of aquatic and terrestrial environments by synthetic fibres, raising concerns among the public and scientific community about their potential to cause harm (Wright *et al* 2013, Acharya *et al* 2021).

Despite the rapid growth of microplastic and microfibre research in recent years, the environmental presence of natural (e.g. wool, cotton, silk) and semi-synthetic fibres (e.g. polymers based on regenerated cellulose such as rayon or lyocell) have often been overlooked. This oversight is likely due to the assumption that their perceived natural origins negate any potential impact they may have, or because the methodologies used (often designed for synthetic plastics analysis) have prevented their detection and led to misidentification (figure 1) (Stanton *et al* 2019). Consequently, natural and semi-synthetic fabrics are being increasingly viewed as sustainable alternatives with negligible environmental impact, but unbiased scientific evidence is not conclusive of that.

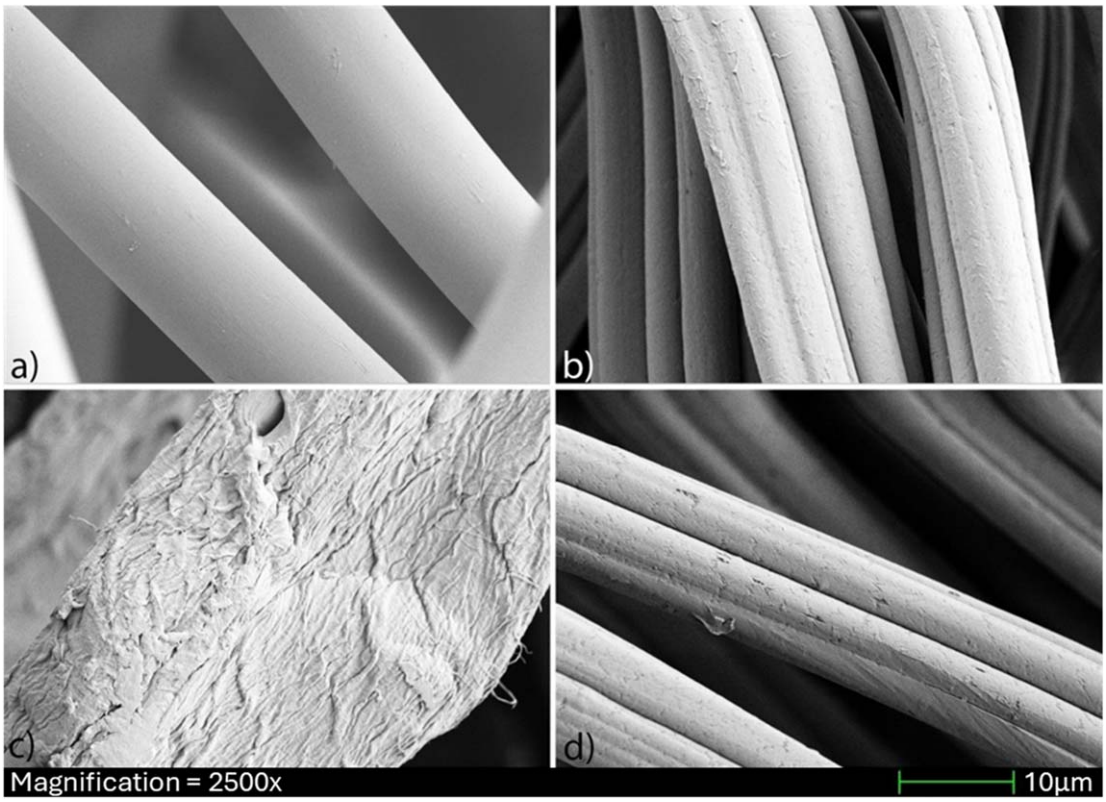

Figure 1. Electron micrograph of common microfibres: a) Synthetic PET, b/d) semi-synthetic rayon/ lyocell (regenerated cellulose), c) cotton. Due to the small size of microfibres, identification using spectroscopic or visual techniques can lead to misidentification or missed observations.

Table 1. Literature definitions of synthetic, natural, and semi synthetic fibres.

Term	Definition
Synthetic Fibre	Composed of polymers produced entirely from anthropogenic sources, most generally from petroleum byproducts (Saba and Jawaid 2017).
Semi-Synthetic Fibre	Derived from natural materials that have been reconstructed, generally by manufactured synthetic substances (Sulakhe 2022).
Natural Fibre	Composed of purely natural fibrous sources, such as plant, animal or mineral fibres (Majid *et al* 2020).

The need for clear and universal definitions

Over the last decade there has been a shift in focus in fibre research, with more studies such as Stanton *et al* (2019), Volgare *et al* (2022) and Dehhaghi & Pardakhti (2023) reporting the presence and high proportion of natural and semi-synthetic textile fibres as components of microplastic pollution in the environment. Still, there is a lack of understanding of the behaviour and impact of natural and semi-synthetic fibres and whether these fibres should even be classified as 'natural'. Stanton *et al* (2024) noted how some 'natural' textile fibres cannot be classified as such, due to the extensive chemical processing during manufacturing of the polymer itself (table 1). Switching from synthetic to natural and semi-synthetic fabrics has the potential to 'greenwash' both the industry and consumers, due to a lack of transparency regarding the chemicals used within textile production, and the assumption that natural fibres readily degrade into harmless constituents (Delmas & Burbano 2011). Here, we call for further research and the need for collaboration to help us understand the potential environmental impact of these fibres and their associated chemicals.

The overlooked threat of chemical additives

Throughout the production of textiles, a range of chemicals are utilised, which are referred to as chemical additives (Athey *et al* 2022). Natural, semi-synthetic and synthetic fabrics are subjected to chemical processing to increase functionality and improve performance. For instance, flame retardants, used to reduce flammability of

certain fabrics, are added in the form of halogenated compounds such as chlorinated paraffins or polydecabrominated diphenyl esters which have been linked to neurotoxic effects across a range of organisms (Xue *et al* 2023). To create resistance and improve dye fastness, silicone-based softeners and formaldehyde-based resins are added to fabrics, which have been shown to bioaccumulate and be carcinogenic (Ji *et al* 2024). Several bisphenols (i.e., BPA, BPB) and benzophenones are used in the textile industry as coatings for UV stabilisation, as finishing agents to increase durability and in the manufacturing of dyes (European Environment Agency 2024). Meanwhile, BPA is classified as a hazardous chemical within the EU, and Germany suggests the use of BPB should be restricted (European Environment Agency 2024). Furthermore, it has been identified that wool fibres can have a higher concentrations of bisphenols and benzophenones compared to polyester fibres, thus highlighting the need for further research into the potential release of chemicals from non-synthetic fibres and other fibre types, with specialised interest into natural and semi-synthetic fabrics (Sait *et al* 2021). Moreover, the precise composition, concentration, and chemical cocktail of the additives used within clothing production (and associated released microfibres (Browne *et al* 2011) are largely unknown. This lack of transparency complicates the risks to aquatic and terrestrial ecosystems associated with exposure to chemically laden microfibres.

The ecological implications of natural and semi-synthetic fibre pollution

The ecotoxicological consequences of 'natural' and 'semi-synthetic' textile fibres have not been extensively investigated, with only a handful of studies exploring their impact on biota. Ingestion of fibres has been demonstrated to influence the development of juvenile invertebrates exposed to cotton microfibres (Dos Santos *et al* 2024, Siddiqui *et al* 2023, Walkinshaw *et al* 2023), and ingestion of rayon microfibres increased oxidative stress, altered the gut microbiome and reduced enzyme activity within mussels (*Mytilus coruscus*) (Jiang *et al* 2024). Détrée *et al* (2023) demonstrated that the morphology of wool and cotton, combined with the chemical additives associated with them, triggered oxidative stress and perturbed digestive function in oysters (*Crassostrea gigas*), higher than those exposed to synthetic fibres. This could stem from the more rapid degradation of natural and semi-synthetic fibres compared to synthetics, then release additives at a higher concentration over a shorter timescale. To date, the physical effects of fibre morphology and the chemical effects associated with their additives have not been fully researched. It is also unclear as to how the presence and degradation of natural and semi-synthetic fibres may contribute to the occurrence, persistence and bioavailability of chemical additives in the environment. Future research should focus on quantifying and characterising the effects of natural and semi-synthetic textile fibres and their associated additives on the overall health and functioning of organisms, as well as how additives may influence the breakdown of these fibres and their persistence.

Natural and semi-synthetic fibres, a sustainable alternative or additional challenge?

Although natural and semi-synthetic fibres are often perceived as sustainable alternatives to plastic, we urge that further research is needed to understand their potential environmental impact. Whilst it has been well established that synthetic fibres persist in the environment and may cause negative ecotoxicological effects, the effects of natural and semi-synthetic fibres are still largely unknown. A current gap in the scientific literature between the residency of fibres and their associated additives must be further explored, Therefore, caution is advised when considering natural textiles as safer alternatives to synthetic polymers, and further research is needed to fully understand the environmental impacts throughout their lifecycle, from manufacture to disposal, relative to synthetic textiles.

Acknowledgments

Thanks to Anglia Ruskin University for funding and hosting the workshop that led to this collaboration. Thanks to the University of East Anglia and the NERC ARIES Doctoral Training Pathway for partly facilitating this research.

Data availability statement

No new data were created or analysed in this study.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

ORCID iDs

Daniel J Jolly https://orcid.org/0009-0002-1716-5103
Brigitta Olah-Kovacs https://orcid.org/0009-0003-9152-9195
Charlotte Woodhouse https://orcid.org/0009-0007-8191-8575
Amy C M Wright https://orcid.org/0000-0001-9333-4613
Trevor J Tolhurst https://orcid.org/0000-0002-8578-7580
Dannielle S Green https://orcid.org/0000-0002-9122-8160

References

Acharya S, Rumi S S, Hu Y and Abidi N 2021 Microfibers from synthetic textiles as a major source of microplastics in the environment: a review *Textile Res. J.* **91** 2136–56

Athey S N, Carney Almroth B, Granek E F, Hurst P, Tissot A G and Weis J S 2022 Unraveling physical and chemical effects of textile microfibers *Water* **14** 3797

Browne M A, Crump P, Niven S J, Teuten E, Tonkin A, Galloway T and Thompson R 2011 Accumulation of microplastic on shorelines eoldwide: sources and sinks *Environmental Science & Technology* **45** 9175–9

Dehhaghi S and Pardakhti A 2023 Characterization of microplastics in the atmosphere of megacity Tehran (Iran) *Environmental Science and Pollution Research* **30** 106026–37

Delmas M A and Burbano V C 2011 The drivers of greenwashing *Calif. Manage. Rev.* **54** 64–87

Détrée C, Labbé C, Paul-Pont I, Prado E, El Rakwe M, Thomas L, Delorme N, Le Goïc N and Huvet A 2023 On the horns of a dilemma: evaluation of synthetic and natural textile microfibre effects on the physiology of the Pacific oyster *Crassostrea gigas Environ. Pollut.* **331** 121861

Dos Santos J B *et al* 2024 Are microfibers a threat to marine invertebrates? A sea urchin toxicity assessment *Toxics* **12** 753

European Environment Agency 2024 Human Exposure to Bisphenol A in Europe. Available at:https://www.eea.europa.eu/publications/peoples-exposure-to-bisphenol-a (Accessed: 03/10/2024)

Ji X, Liu J, Shen J, Su P, Liang J, Feng X, Liu X and Liu R 2024 Characterization of chemical additives in daily clothing regarding human exposure and environmental emissions *Environmental Science & Technology Letters* **11** 619–25

Jiang N, Chang X, Huang W, Khan F U, Fang J K H, Hu M, Xu E G and Wang Y 2024 Physiological response of mussel to rayon microfibers and PCB's exposure: overlooked semi-synthetic micropollutant? *J. Hazard. Mater.* **470** 134107

Majid M A, Ridzuan M J M and Lim K H 2020 Effect of nanoclay filler on mechanical and morphological properties of napier/epoxy composites *Interfaces in Particle and Fibre Reinforced Composites* (Woodhead Publishing) 137–62

Saba N and Jawaid M 2017 Epoxy resin based hybrid polymer composites *Hybrid Polymer Composite Materials* ed V Kumar Thakur, M Kumari Thakur and A Pappu (Woodhead Publishing) 57–82

Sait S T, Sørensen L, Kubowicz S, Vike-Jonas K, Gonzalez S V, Asimakopoulos A G and Booth A M 2021 Microplastic fibres from synthetic textiles: environmental degradation and additive chemical content *Environ. Pollut.* **268** 115745

Siddiqui S, Hutton S J, Dickens J M, Pedersen E I, Harper S L and Brander S M 2023 Natural and synthetic microfibers alter growth and behavior in early life stages of estuarine organisms *Frontiers in Marine Science* **9** 991650

Stanton T, James A, Prendergast-Miller M T, Peirson-Smith A, KeChi-Okafor C, Gallidabino M D, Namdeo A and Sheridan K J 2024 Natural fibers: why are they still the missing thread in the textile fiber pollution story? *Environmental Science & Technology* **58** 12763–6

Stanton T, Johnson M, Nathanail P, MacNaughtan W and Gomes R L 2019 Freshwater and airborne textile fibre populations are dominated by 'natural', not microplastic, fibres *Science of The Total Environment* **666** 377–89

Sulakhe V N 2022 Introduction to semisynthetic and synthetic fiber based composites *Natural and Synthetic Fiber Reinforced Composites: Synthesis, Properties and Applications* (John Wiley & Sons) 67–79

Volgare M, Santonicola S, Cocca M, Avolio R, Castaldo R, Errico M E, Gentile G, Raimo G, Gasperi M and Colavita G 2022 A versatile approach to evaluate the occurrence of microfibers in mussels *Mytilus galloprovincialis Sci. Rep.* **12** 21827

Walkinshaw C, Tolhurst T J, Lindeque P K, Thompson R C and Cole M 2023 Impact of polyester and cotton microfibers on growth and sublethal biomarkers in juvenile mussels *Microplastics and Nanoplastics* **3** 5

Wright S L, Thompson R C and Galloway T S 2013 The physical impacts of microplastics on marine organisms: a review *Environ. Pollut.* **178** 483–92

Xue J, Xiao Q, Zhang M, Li D and Wang X 2023 Toxic effects and mechanisms of polybrominated diphenyl ethers *Int. J. Mol. Sci.* **24** 13487