Microfibre Pollution and the Marine Biodegradation of Wool

The contamination of the environment with fibres and fragments from textiles (so called 'microfibre pollution') is of growing concern. An important source of this pollution is fibre shedding during laundering. We are investigating the fate of fibres once they enter the aquatic environment.

The seemingly ubiquitous contamination of the environment with fibres and fragments from textiles [1] (so-called 'microfibre pollution') is of growing concern. A substantial source of this pollution appears to be fibre lost from garments during laundering, into wastewater [2-4], with synthetic fleece-type fabrics reportedly among the worst culprits [5]. Most research has focused on where fibres are found in the environment and their relative prevalence (e.g. [6]) and on measuring the extent to which they are shed during laundering (e.g. [2]). In our research we are focused on another aspect: the ultimate fate of fibres, and wool in particular, in the aquatic environment.

There has been much research on biodegradation of wool on land (for example, wool carpets [7], apparel [8] and geotextiles [9]), but far less is known of its behaviour in the aquatic environment. One early study [10] showed that wool biodegraded in the natural marine environment, demonstrating there are microorganisms in the ocean that biodegrade wool keratin. In a more recent study [11], wool and cotton were found to biodegrade readily compared to polylactic-acid fibres in an aqueous environment. In contrast, in water-logged archaeological deposits human hair and wool textiles are sometimes preserved because microbial activity is reduced [12]. However, these conditions are not at all typical of aquatic environments such as lakes, rivers and oceans.

Our Research

Our goal was to measure the biodegradation of wool and competing fibres in the marine environment, and study the residues produced. This was done using a method [13] based on an established standard [14] for measuring marine biodegradation. Residues were examined using scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX).

The samples were comparable lightweight base-layer fabrics made from two types of merino wool, viscose rayon, polyester, nylon (i.e. polyamide) and polypropylene, which had been deconstructed (shredded) to remove interference from fabric structure effects. Fabrics had been washed repeatedly before testing, to simulate a partial garment lifetime.

The amount of biodegradation of the fibres is expressed relative to a 'positive control', i.e. a sample known to biodegrade readily. In our work this was kraft paper pulp. The average biodegradation of three samples for each fibre type relative to the control was measured.

Fibre Type	Relative Biodegradation
Control (paper pulp)	100
Untreated Wool	20.3
Machine-washable Wool	67.3
Viscose rayon	64.5
Polyester	6.3
Nylon	0.8
Polypropylene	1.8

Table 1: Relative biodegradation of fibre types.

Both types of wool biodegrade to a high degree, as does the cellulose-based viscose rayon. Synthetic fibres show little or no biodegradation. The treatment that makes wool machine-washable, preventing felting by applying a thin film to the fibre surfaces [15], actually caused the wool to biodegrade more rapidly than untreated wool. This is probably because the treatment process removes some of the fibre's cuticle, rendering it more susceptible to microbial degradation.

Based on observations from soil biodegradation we expect that over a relatively short time wool will biodegrade completely in the marine environment. The rate of biodegradation for untreated wool is likely to increase to be similar to that of machine-washable wool once its cuticle is broken down.

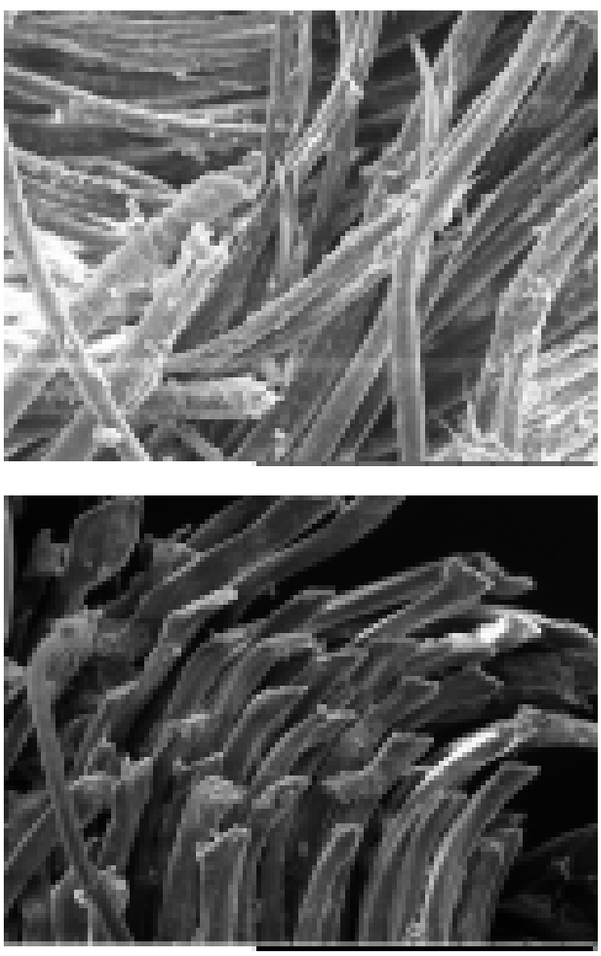

Figure 1: Machine-washable wool (top) and polyester (bottom). Scale bar is 200 µm.

Representative SEM images of residues from some fibres are shown. The degradation of wool is clear, as is the lack of degradation of the synthetic fibres.

One concern raised about the use of the commonly used resin (Hercosett), which is a polyamide, on machine-washable wool is that the resin might break into fragments as the wool fibre degrades, creating a form of microplastic pollution. We used EDX to study the composition of fragments observed under SEM in the fibre residues. We looked specifically for the presence of sulfur, as this would be absent from any polyamide resin fragments but would be present in wool fibre fragments. The average composition of fragments from the residue of the machine-washable wool samples was 47.8% carbon, 20.0% nitrogen, 28.9% oxygen and 3.3% sulfur, which is consistent with the composition of the wool. Most importantly, all fragments had sulfur present at levels greater than 2.5%, meaning that they were almost certainly derived from wool. In other words, we did not detect the formation of microplastic polyamide fragments resulting from the biodegradation of machine-washable wool.

It is important to note that the crosslinked polyamide resin used in the machine-wash treatment for wool is very different from common commercial polyamides. This resin is initially water soluble when applied to the wool surface, where its light crosslinking prevents re-solution. In this form the resin is able to swell significantly in water so that it more effectively masks the fibre scales, enhancing machine-washability. This swelling potentially means that it presents a much-reduced barrier to microbial access.

Key Findings

- Both untreated wool and machine-washable wool were found to biodegrade readily in the marine environment, and synthetic fibres were not.
- In our research machine-washable wool biodegraded even faster than untreated wool
- We found no evidence to support the idea that the polyamide resin used as part of the machine-washable treatment forms microplastic pollution.

References

1. M Kosuth, SA Mason, EV Wattenberg, Anthropogenic contamination of tap water, beer, and sea salt, PLoS ONE, 2018, Vol. 13, No. 4, e0194970.
2. IE Napper, RC Thompson, Release of synthetic microplastic plastic fibres from domestic washing machines: Effects of fabric type and washing conditions, Marine Pollution Bulletin, 2016, Vol. 112, No. 1-2, 39-45.
3. F De Falco, E Di Pace, M Cocca, M Avella, The contribution of washing processes of synthetic clothes to microplastic pollution, Scientific Reports, 2019, Vol. 9, No. 1, art. no. 6633.
4. F Salvador Cesa, A Turra, J Baruque-Ramos, Synthetic fibers as microplastics in the marine environment: A review from textile perspective with a focus on domestic washings, Science of the Total Environment, 2017, 598, 1116-1129.
5. BM Carney Almroth, L Åström, S Roslund, H Petersson, M Johansson, M, N-K Persson, Quantifying shedding of synthetic fibers from textiles; a source of microplastics released into the environment, 2018, Environmental Science and Pollution Research, 25 (2) 1191-1199.
6. D Santillo, K Miller, P Johnston, Microplastics as contaminants in commercially important seafood species, Integrated Environmental Assessment & Management, 2017, Vol. 13, No. 3, 516-521.
7. SJ McNeil, MR Sunderland, LI Zaitseva, Closed-loop wool carpet recycling, Resources, Conservation and Recycling, 2007, Vol. 51 No. 1, 220-224.
8. A Hodgson, RH Barker, C van Koten, SR Collie, Wool: A Compostable Substrate? Proceedings of the 43rd Textile Research Symposium, Christchurch (New Zealand), 2014.
9. J Broda, S Przybyło, K Kobiela-Mendrek, D Biniaś, M Rom, J Grzybowska-Pietras, R Laszczak, Biodegradation of sheep wool geotextiles, International Biodeterioration and Biodegradation, 2016, Vol. 115, 31-38.
10. RM Brown, The Microbial Degradation of Wool in the Marine Environment, MSc Thesis, University of Canterbury 1994.
11. Y Sing, J Luo, A Ni, Y Bi, W Yu, Study on the Biodegradability of Wool and PLA Fibers in Natural Soil and Aqueous Medium, Advanced Materials Research, 2013, Vols. 641-642, 82-86.
12. C Solazzo, JM Dyer, S Clerens, J Plowman, EE Peacock, MJ Collins, Proteomic evaluation of the biodegradation of wool fabrics in experimental burials, International Biodeterioration and Biodegradation, 2013, Vol. 80, 48-59.
13. SR Collie, SL Ranford, PH Brorens, SL Ranford, Microfibre Pollution – What's the Story for Wool? Proceedings of AUTEX 2019 – 19th World Textile Conference, Ghent, June 2019.
14. ASTM D6691 – 09: Standard Test Method for Determining Aerobic Biodegradation of Plastic Materials in the Marine Environment by a Defined Microbial Consortium or Natural Sea Water Inoculum.
15. MM Hassan, CM Carr, A review of the sustainable methods in imparting shrink resistance to wool fabrics, 2019, Journal of Advanced Research, 18, 39-60.

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