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LIGHT-INDUCED STRENGTH LOSS IN JUTE AND POLYPROPYLENE CARPET BACKING FABRICS

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Abstract: *The closed-loop recycling of mechanically shredded post-consumer wool-pile carpets as fertiliser was demonstrated previously, where it increased the yield of grass by up to 82%. When cultivated into the soil, the shredded carpet inevitably left fragments on the surface, which included jute and polypropylene components of the carpet backing. To determine their likely persistence in the environment, jute and polypropylene carpet backing fabrics were subjected to intense light from a 500-Watt lamp, which provided a reasonable approximation to sunlight outdoors. The changes in mechanical properties and microscopic appearance of the fabrics were monitored. Over 500 hours of exposure to light (equivalent to 125 days of strong sunlight), the jute lost 60% of its strength. The polypropylene lost strength more rapidly than the jute, i.e. 88% loss over 250 hours. In an outdoor situation, the jute and polypropylene would be subject to rain and microbial action, as well as sunlight, so degradation will be faster than was measured under laboratory conditions. The results of this study suggest that fragments of jute and polypropylene carpet backing, on the surface of soil, may not constitute an environmental hazard, and that photodegradation of microplastic fibres on land (such as those in waste water sludge applied to land), reduces the risk they pose to aquatic environments.*

Key words: *wool carpet recycling, jute, polypropylene, photodegradation, mitigating microplastic pollution*

1. INTRODUCTION

There is growing interest in reducing the amount of textile waste that is disposed of in landfills or by incineration [1]. The increasing consumption of textiles, fuelled by the growth of fast fashion, has contributed to this interest [2]. Consumers who choose wool, tend to be well informed and environmentally aware, so the wool industry has endeavoured to stay at the forefront of sustainability, by developing many new technologies [3], including the recycling of carpets [4]. In addition, wool can be used in non-traditional products designed to enhance the environment, by for instance, removing heavy metals and dyes from waste water [5],[6] and removing pollutants from indoor air [7].

Wool is unique amongst the fibres commonly used in carpet piles, as it is biodegradable in the soil [8] and oceans [9]. This biodegradability in soil enables wool to be used as a fertiliser. The recycling of post-consumer wool-pile carpets was shown by using mechanically shredded wool-pile carpet as a fertiliser, increasing the yield of pasture by up to 82% [10], thereby demonstrating closed loop recycling, i.e. grass-wool-carpet-grass. This type of recycling of post-consumer wool-pile carpet would not only help to alleviate the problem of waste disposal, it would increase soil fertility and reduce the use of other types of fertilisers.

Carpet have been made entirely with wool, i.e. wool pile, wool primary and secondary backing fabrics and solubilised wool latex [11], but, at present, most wool carpets contain jute and polypropylene, see **Fig. 1**. Therefore, the behaviours of jute and polypropylene in wool carpet fertiliser need to be considered. Some jute and polypropylene will end-up on top of the soil, where they will break-down by a combination of microbial and photochemical processes.

There is growing concern about the liberation of microplastic fibres during the laundering of clothing made from synthetic fibres. It has been estimated that laundering generates 0.12 kg of microplastic fibres per person per year [12], making a significant contribution to plastic pollution of rivers, lakes and oceans [13]. Microplastic fibres produced by laundering can, to various degrees, be intercepted by waste water treatment plants [14]. However, sludges from these plants are often applied to land, so that wind and rain can transport the microplastic fibres to waterways. Any photochemical degradation of the microplastic fibres would affect the risk they pose to waterways.

The work reported here investigated the changes in tensile strength and microscopic appearance of jute and polypropylene fabrics caused by exposure to light.

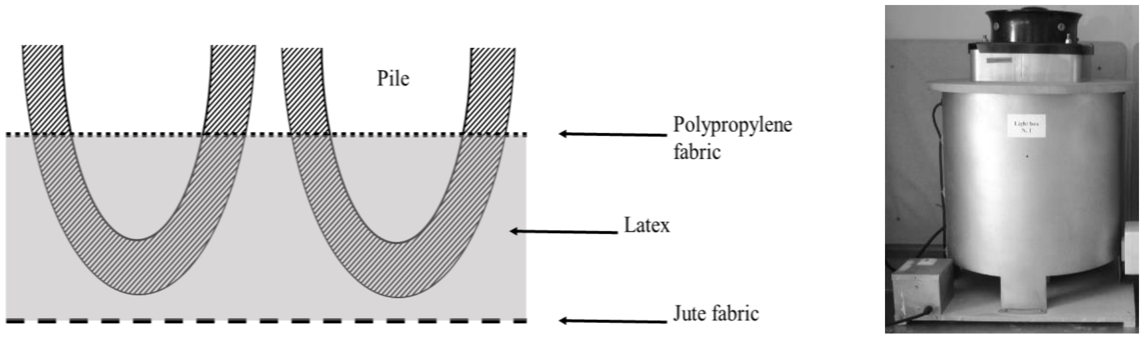

Fig. 1*: Schematic view of carpet cross-section (left) and light box (right)*

2. MATERIALS AND METHODS

The jute was a standard woven carpet backing fabric of 217 g/m^2 of unknown origin. The polypropylene was a standard woven primary carpet backing fabric of 115 g/m^2 (Poly Bac LPB 2805, Amoco, Australia). The polypropylene was manufactured for indoor use and would therefore not contain light stabilisation additives. Fabrics (70 mm × 200 mm) were exposed to a 500-Watt lamp in a light box with forced circulation of air, see **Fig. 1**. The fabrics were mounted 85 mm from the outside of the lamp (120 mm from the vertical axis of the lamp) and revolved around the lamp at one revolution per hour. The lamp was a mercury vapour, tungsten filament, internally phosphor-coated lamp (HSB-BW, Sylvania, Belgium). Fabrics were exposed to the lamp for various times up to 1,000 hours. The lamp was turned off every 48 hours for 16 hours, to approximate day and night that would be encountered outside. This type of lamp was chosen as it is commonly used to assess the photo-fading of textiles, emits light that is a reasonable approximation for sunlight (310-760 nm) and exposure of 4 weeks (672 hours) is known to be approximately equivalent to six months outdoor exposure under strong sunlight conditions (i.e. summer, latitude 23° south, in Barcaldine, Queensland, Australia) [15]. It was desirable to use an artificial light source, so that this study could be reproduced by different laboratories, and not be dependent upon local climatic conditions.

Exposed and unexposed fabrics had their tensile properties measured by the Woolmark Company Test Method 4 (Breaking Strength of Fabric). The tensile testing was performed in triplicate with a crosshead speed of 200 mm/minute, a gauge length of 200 mm and a width of 50 mm. Selected fabrics were examined by field emission scanning electron microscopy with a JSM 7000F (JEOL, Japan), after sputter coating from a gold-palladium source.

3. RESULTS AND DISCUSSION

The polypropylene was stronger than the jute initially, but the polypropylene had a greater rate of strength loss during light exposure. After some 250 hours of exposure, the two types of fabric had the same breaking strength, and as exposure continued, the polypropylene became considerably weaker than the jute. The mean breaking strengths, and extensions at break of the fabrics are shown in **Figs. 2** and **3**. After 500 hours exposure, the polypropylene fabric was too weak to be mounted in the tensile testing instrument. After 500 hours of exposure, the jute did not get any weaker with continued exposure beyond 500 hours.

The extension at break of the polypropylene followed the same trend as its breaking force. The extension at break of the jute was initially lower than that of the polypropylene, but it was largely unaffected by the light. By 250 hours of exposure, the jute had a greater extension at break than the polypropylene.

In some cases, short exposures (25 hours) slightly increased breaking strength, and extension at break, during. This could have been caused by light-induced cross-linking, such as that imparted to polypropylene by the photolysis of hydroperoxide [16]. As the light exposure was continued beyond 25 hours, radical-induced cleavage of bonds would weaken the fabrics. The losses in strength and extension at break of the jute and polypropylene were accompanied by microscopic cracking, see **Figs. 4-7**.

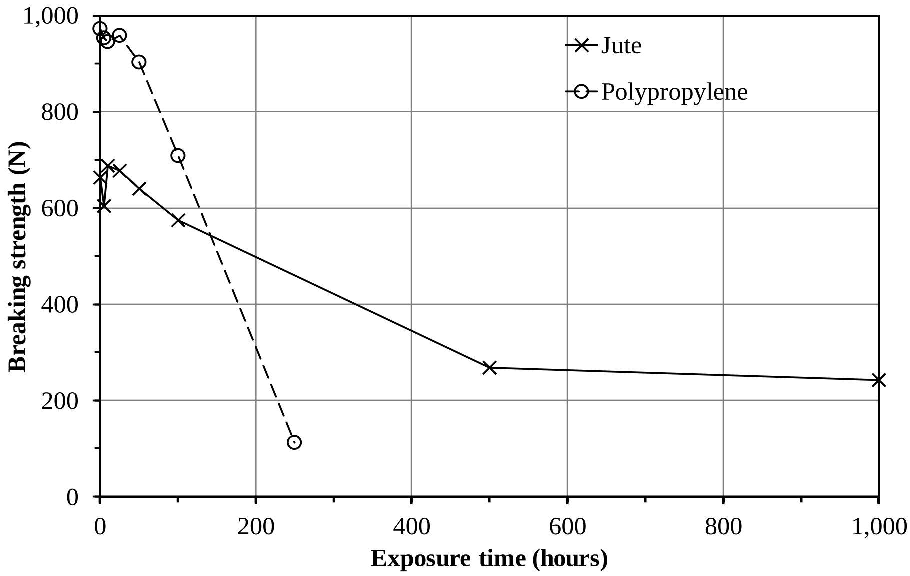

Fig. 2*: Breaking strengths of jute and polypropylene carpet backing fabrics after exposure to a 500 W lamp. NB the polypropylene fabric was too weak to measure after 500 hours*

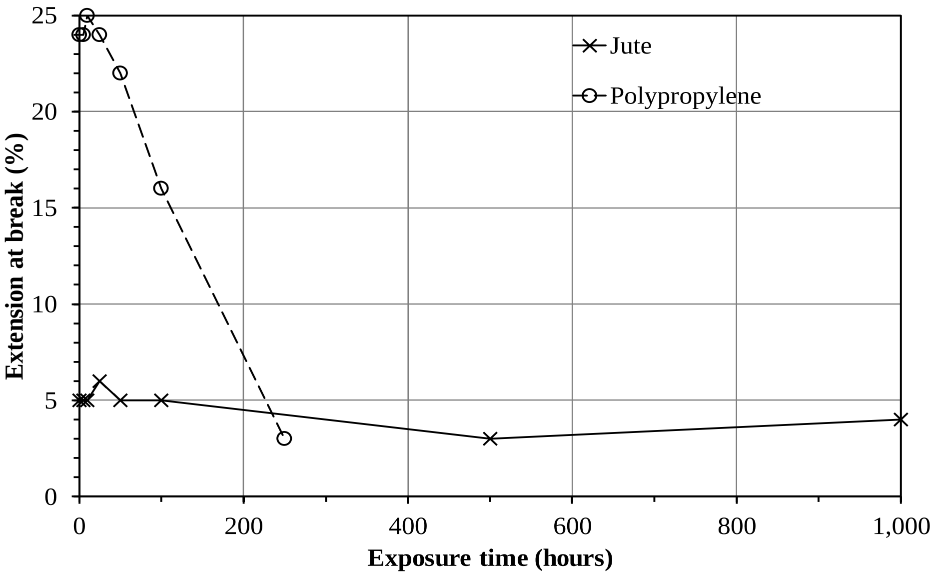

Fig. 3*: Breaking extensions of jute and polypropylene carpet backing fabrics after exposure to a 500 W lamp. NB the polypropylene fabric was too weak to measure after 500 hours*

The susceptibility of the jute and polypropylene (and other components of shredded wool-pile carpets) to degradation by photochemical and microbial processes, could be increased by conventional textile processes, such as oxidation, enzyme hydrolysis, heat, or by emerging ones such as plasma [17].

Fibres and microplastic fibres applied to land in sludges from waste water treatment plants [18], could reasonably be expected to show similar photodegradation to that observed in this study, thus reducing the risk they pose to aquatic environments.

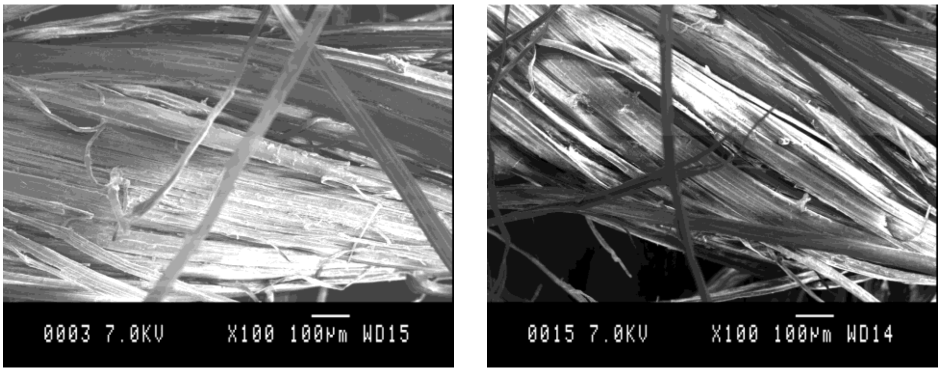

Fig. 4*: Micrographs of jute fabric, unexposed (left) and exposed for 100 hours (right)*

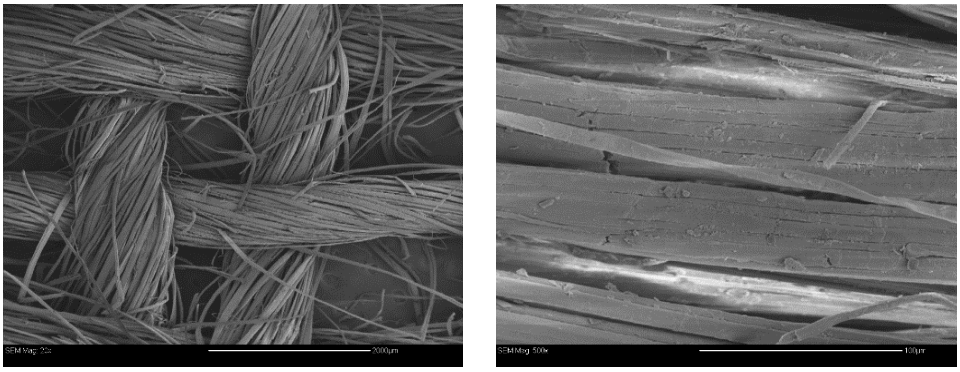

***Fig. 5**: Micrographs of jute fabric exposed for 1,000 hours (scale bars 2,000 µm left, 100 µm right)*

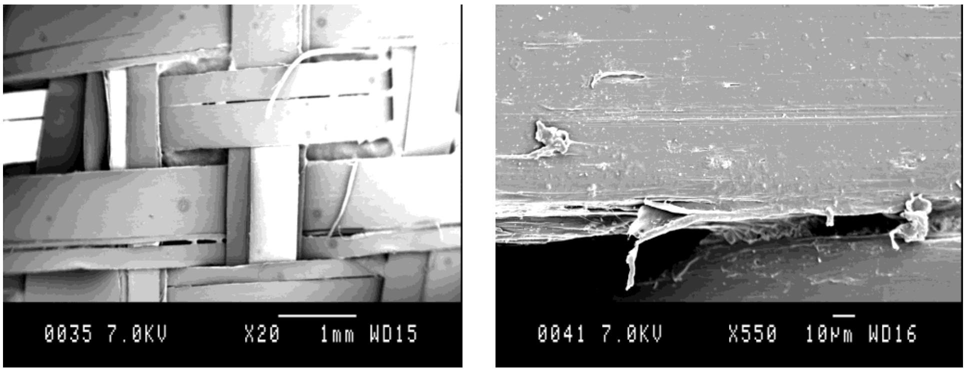

***Fig. 6**: Micrographs of unexposed polypropylene fabric*

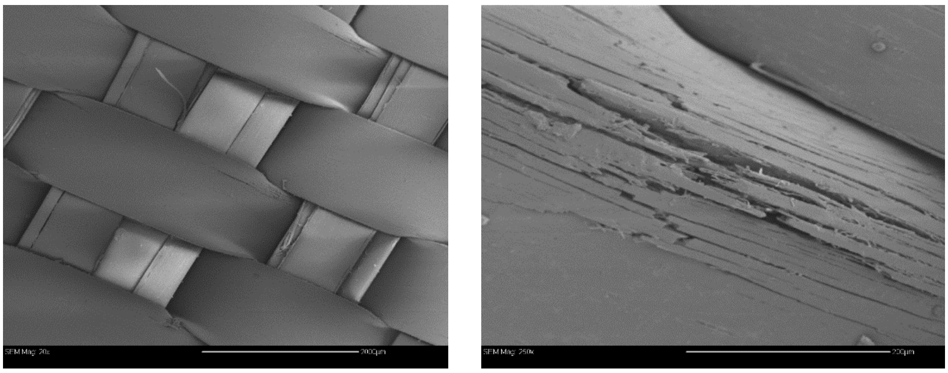

***Fig. 7**: Micrographs of polypropylene fabric exposed for 250 hours (scale bars 2,000 µm left, 200 µm right)*

4. CONCLUSIONS

Jute and polypropylene carpet backing fabrics lost most of their strength when exposed to intense light, with polypropylene having the greater rate of strength loss. The action of microbes and water on fabrics outdoors could reasonably be expected to increase the rate of fabric damage compared with those reported here. These results suggest that fragments of jute and polypropylene in shredded wool-pile carpet fertiliser, on the surface of soil, would be readily degraded by sunlight. These results also suggest that microplastic fibres applied to land in sewage sludge and exposed to sunlight would be photodegraded, potentially reducing the risk they pose to aquatic environments.

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