The Microfibre Consortium

Leading the textile industry in reducing microfibre release to protect our environment

Technical Research Report: Recycled Polyester within the context of Fibre Fragmentation

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This report has been prepared using information collected from fabric test data housed in the TMC Data Portal between the 12th of March 2020 and the 1st of March 2023. As further data is collected, it may be necessary to revise the findings and conclusions. Our results are reliant on the accuracy of the information supplied by signatories.

TMC's position on recycled polyester in the context of fibre fragmentation

The increase in use of recycled polyester (rPET) has been steadily growing since 1993 in response to the growing sustainability needs within the clothing sector. In 2021, rPET represented 14.8% of global PET production.

When the industry adopts new materials, it is vital to consider their impact holistically and ensure they are not causing unintended, invisible consequences somewhere else. Thus, The Microfibre Consortium (TMC) in collaboration with a handful of research groups conducted a small-scale study of the effect of recycled polyester fibres on fibre fragmentation in finished fabrics. TMC concluded that in order to make commercial decisions at an industry level, a larger collaborative and industry facing approach was needed.

A clear business need for science driven research was required that had a strong methodology, a consistent test method (The Microfibre Consortium Test Method [1]), and a large and diverse data set from commercial fabrics (The Microfibre Data Portal [2]). The learnings from the early rPET research could then be developed further by engaging the signatories of The Microfibre 2030 Commitment and disseminated for the greater good of the larger industry.

A specific call-to-action to TMC's brand and retailer signatories to test 100% polyester fabrics (recycled or virgin), using The Microfibre Consortium Test Method[1], resulted in data from a total of 251 fabrics, across a range of fabric specifications. The data, incorporating 2,977 individual sample data points, was analysed to determine how the replacement of virgin polyester with recycled polyester affected fibre fragmentation.

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[1] The Microfibre Consortium Test Method: quantification of fibre release from fabrics during simulated domestic laundering (The TMC Test Method) is an aligned and standard test method to determine fibre loss from fabrics which reflects domestic laundering, during the initial washing cycle.

The TMC Test Method has been developed through the collaborative relationship between The University of Leeds, European Outdoor Group and The Microfibre Consortium as well as the larger stakeholder network. Using ISO 105-C06 at its core, it has been developed to use standard laboratory equipment and provide accurate comparable data, in a manner that can be scaled commercially across a range of laboratory facilities.

Using a harmonized test method is critical to remove variables related to washing conditions, enabling fabric to fabric comparison.

[2] The Microfibre Data Portal: an industry-first data repository housing both testing data and technical specifications of fabrics tested using The Microfibre Consortium Test Method.

Data can only be uploaded to The Microfibre Data Portal when fabric technical specifications are provided and the TMC Test Method is performed at an accredited laboratory. Material specification information is uploaded to The Microfibre Data Portal by signatories of The Microfibre 2030 Commitment and test results are uploaded by the accredited laboratory technician performing the test. This ensures data quality and consistency and prevents any data manipulation. This provides the ability to scale and compare data from a diversity of materials from a depth of global suppliers across the industry. At the time of writing The Microfibre Data Portal holds test data from 613 fabrics and is believed to be the largest global data set on fibre fragmentation of textiles.

Following analysis of the data, TMC's position on recycled polyester in the context of fibre fragmentation is:

1. **Mechanically recycled polyester does not seem to have a detrimental effect on fibre fragmentation compared to virgin polyester.** Based on current data, mechanically recycled polyester fabrics, overall, fragmented to the same extent as those made from virgin polyester.

2. **TMC cannot currently comment on chemically recycled polyester** due to the lack of data. TMC acknowledges that chemically recycled polyester is in its infancy and calls the industry to action to increase testing, when available, so that further analysis can be undertaken.

3. **Fibre fragmentation remains a concern, for all textiles including polyester materials, whether virgin or recycled.** Whilst isolated studies of limited samples may indicate differences between variables (e.g., rPET v vPET), those effects may not translate across a large data set containing a multitude of different fabric specifications such as yarn size, fabric construction, weight etc. This reinforces the importance of a substantive dataset.

4. **TMC reiterate their position that composition alone does not determine the fibre fragmentation/shedding volumes of textiles.** The data analysis from The Microfibre Data Portal reinforces the complexity of fibre fragmentation as a topic due to the inter-dependency of fabric variables. TMC recommends a broader, and deeper analysis across the entire data set.

Contents

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Definitions

Fibre - A generic term for any one of the various types of matter that form the basic elements of a textile, and which are generally defined as having flexibility, fineness, and high ratio of length to thickness.

Fibre Fragment - A short piece of textile fibre, broken from the main textile construction or through its subsequent breakage in the natural environment. This is also sometimes referred to as a microfibre.

(Fibre) Fragmentation - The process of fibre loss from a textile product during its life cycle and / or through its subsequent breakage in the natural environment. This is also referred to as fibre *shedding*.

Microfibre - The textile industry definition of a microfibre is a synthetic fibre with a linear density of less than 1 denier. There is a different understanding of this term in the context of unintended release of fibres and thus subsequent microfibre pollution. To avoid such confusion, fibre fragment/fibre fragmentation is the preferred terminology.

Microplastic - A small piece of plastic debris measuring 5mm or less, found in the environment from the disposal or breakdown of consumer products and industrial waste. Synthetic fibre fragments are considered microplastics.

(Fibre) Release - Quantity of fibres emitted from a textile product during manufacturing, use or end of use and ending up in the natural environment.

The Microfibre Data Portal - A data repository housing testing data and technical specifications of fabrics tested using The Microfibre Consortium Test Method. Data is self-reported by TMC signatories following self-reference testing of fabric samples in accordance with the TMC test method.

The Microfibre Consortium Test Method - Method for determining the quantity of textile material loss from fabrics during simulated domestic laundering.

Circular Economy – A model of production and consumption in which products or materials are shared, reused, repaired, refurbished or recycled. With the aim of reducing waste and emissions.

Polyester – material usually in the form of PET. In most cases a non-biodegradable synthetic polymer. PET is composed of two monomers, 30wt.% of monoethylene glycol (MEG) and 70 wt% of terephthalic acid (TPA).

Recycled Polyester – Polyester that has been reprocessed from reclaimed pre-and/or post-consumer material by means of a manufacturing process, either by mechanical, chemical, or combined processes.

Mechanically Recycled PET – Mechanical recycling (of PET) is the recovery of materials from waste while maintaining the polymers' molecular structure, using processes such as crushing and shredding.

Chemically Recycled PET – Chemical recycling refers to operations that aim to chemically or partially chemically convert collected PET waste into its monomers or other basic compounds.

Virgin Polyester – polyester that is not made from recycled waste polyester, but from previously unused feedstock, usually from a fossil-fuel derived source.

Please refer to TMC Glossary of Terms for a full list of definitions:
https://www.microfibreconsortium.com/tmc-glossary

Introduction

Polyester is the most widely used fibre globally due to its properties and price, with an annual production of around 61 million tonnes and a market share of approximately 54% of global fibre production in 2021 (Textile Exchange, 2022). Most polyester is derived from petrochemicals, a finite resource, with the most commercially used polyester being polyethylene terephthalate (PET). The production of bio-based polyester is increasing, with 0.02% of the polyester production market share coming from biobased materials (Textile Exchange, 2022). PET, in most cases, is a non-biodegradable synthetic polymer. Inappropriate end of use disposal is detrimental to the environment and human health, and the production of PET is energy intensive (Majumdar et al., 2020).

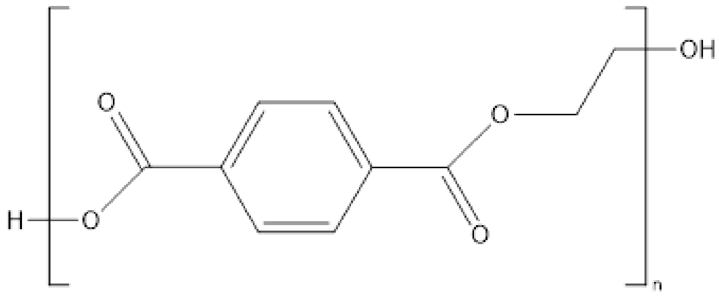

Figure 1: Polyethylene terephthalate (PET) chemical structure.

The textile industry is facing huge environmental challenges due to the large-scale use of chemicals, energy and water, the emission of greenhouse gases (GHGs) and the generation of waste (Majumdar et al., 2020). It is essential that solutions are found within the textile industry to address this. One solution that is seen as a key way to improve sustainability within the apparel textile industry is the use of recycled fibres (Liu et al., 2021).

Key benefits of recycled polyester are the diversion of waste from landfills or incineration, and the reduced consumption of non-renewable resources by replacing the need for virgin feedstock, which in the case of polyester, is usually fossil fuels. This is also thought to reduce GHG emissions. Shen, Worrell and Patel (2010) found reduced global warming potential with the use of recycled polyester over virgin polyester (Shen, Worrell and Patel, 2010).

Recycled Polyester

In 2021, recycled polyester production volume increased from 8.4 million tonnes in 2020 to around 9 million tonnes. This equals a slight increase in the total market share of recycled polyester production from around 14.7% of the global PET production in 2020, to around 14.8% in 2021 (Textile Exchange, 2022).

The increase in recycled polyester production is driven by a desire of the textile industry to reduce environmental impact. In 2021, Textile Exchange launched 'The Textile Exchange 2025 Recycled Polyester Challenge' together with the United Nations Framework Convention on Climate Change's Fashion Industry Charter for Climate Action (UNFCCC), calling for textile companies to commit to sourcing over 45% of their polyester from recycled sources by 2025, with a long-term vision to bring this number up to 90% by 2030 (Textile Exchange, 2022). In just nine months, 132 companies signed up for the challenge.

Recycled Polyester Sources

Recycled polyester fibre can be produced by chemical, semi-chemical or mechanical recycling processes. Recycled polyester textiles can be produced from two sources of PET:

1. Bottle-to-fibre – Recycled from waste PET bottles. The vast majority of recycled polyester is produced by bottle-to-fibre recycling. Bottle-to-fibre recycling can be done by mechanical or semi-chemical recycling.

2. Fibre-to-fibre – Recycled from pre-consumer or post-consumer textiles. This is yet to be commercialised on the same scale as bottle-to-fibre recycling and has some difficulties. For instance, the complexity of clothing materials means that effective sorting and separation are challenging (Keßler, Matlin and Kümmerer, 2021). In 2020, less than 0.5% of recycled polyester originated from recycled textiles (Sigaard and Laitala, 2023).

Mechanical Recycling

Mechanical recycling is the physical conversion of waste PET into fibres or other products by mechanical processes and melt-extrusion (Figure 2). For mechanical recycling, the quality of the fibre produced depends on the waste stream's purity (Shen, Worrell and Patel, 2010). Mechanical recycling is cheaper than chemical recycling (Shen, Worrell and Patel, 2010) and much more common; over 99% of recycled polyester is mechanically recycled (Textile Exchange, 2022). This process can also be referred to as thermo-mechanical recycling.

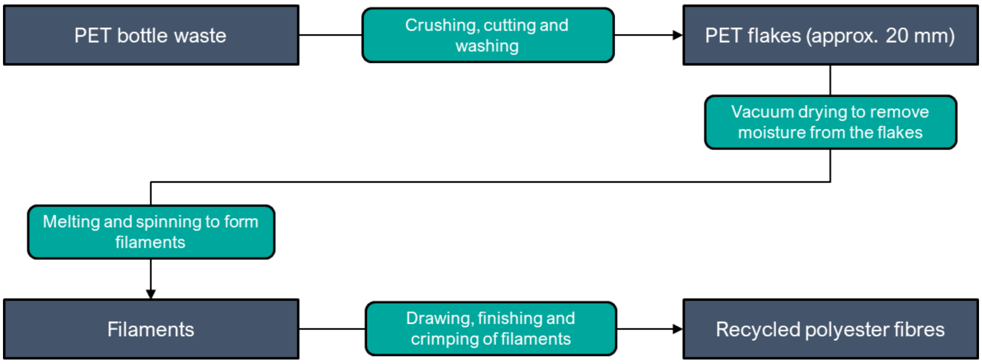

Figure 2: Process of producing recycled polyester fibres mechanically from PET bottles (re-created from Sadeghi et al., 2021).

Chemical Recycling

In chemical recycling, the source material is broken down via various depolymerisation techniques including glycolysis, methanolysis and alkaline hydrolysis. Chemical recycling includes both back-to-oligomer and back-to-monomer recycling (Shen, Worrell and Patel, 2010). Chemical recycling is more expensive than mechanical recycling and may cause a greater environmental burden (Majumdar et al., 2020), but more detailed life cycle analysis is required to quantify the impacts of different chemical recycling processes. The important advantage of chemical recycling is that better quality fibre can be produced (Koo et al., 2013). Back-to-monomer recycling produces polyester identical to virgin polyester. Back-to-oligomer recycling produces polyester that has very similar properties to virgin polyester, but lower dyeability (Shen, Worrell and Patel, 2010).

In some cases, a combination of mechanical and chemical processes are used, this process can be referred to as semi-chemical or semi-mechanical.

Recycled Polyester Concerns

The uptake and use of recycled polyester within the textile and apparel industry has its limitations. In contrast to Shen, Worrell and Patel (2010), Qian et al. found recycled polyester to have a greater carbon footprint than virgin polyester (Qian et al., 2021). This suggests that more research is required to understand how GHG emissions from virgin and recycled polyester production compare. There are also potential quality and performance differences between recycled and virgin polyester fabrics.

Associated increased costs and availability of recycled polyester to the textile industry, due to the competition for the supply of post-consumer bottles for bottle-to-fibre recycled polyester, must too be considered. An estimated 99% of recycled polyester is made from PET plastic bottles (Textile Exchange, 2022). The development of textile-to-textile recycling technology is important to ensure there is sufficient future feedstock and reduce reliance on waste PET bottles.

There is also concern that by producing fibres from recycled polyester bottles, the textile industry is removing waste from a potentially circular economy, and adding it to a linear one, as the PET bottle-to-bottle recycling industry is well established (Welle, 2011), but textile-to-textile recycling is still uncommon (Sigaard and Laitala, 2023). There are also some suggestions that recycled polyester sheds more microfibres during the textile manufacturing stage (Forum for the Future, 2023).

Fibre Fragmentation

Microfibres, are fibre fragments lost from natural, synthetic and man-made cellulosic textiles throughout a products lifecycle. The term microfibre is context dependent. Within the textile industry, microfibre is the technical term for a synthetic fibre with a linear density of less than 1 denier. However, in the context of unintended loss of fibres from textiles and their subsequent release to the environment, the term microfibre(s) is commonly used. To avoid confusion, the term fibre fragment can be used instead. In the context of environmental pollution, synthetic fibres are classed, and described as being microplastic(s).

Reaching the environment through a number of pathways, we know that microfibres have the potential to cause harm through their presence in our ecosystems from marine and freshwater environments to air and soil (Athey et al., 2022) (Figure 3). Textiles are the biggest source of microfibres in the environment, released at all stages of their life cycle, during manufacture, washing and wearing (Weis and De Falco, 2022).

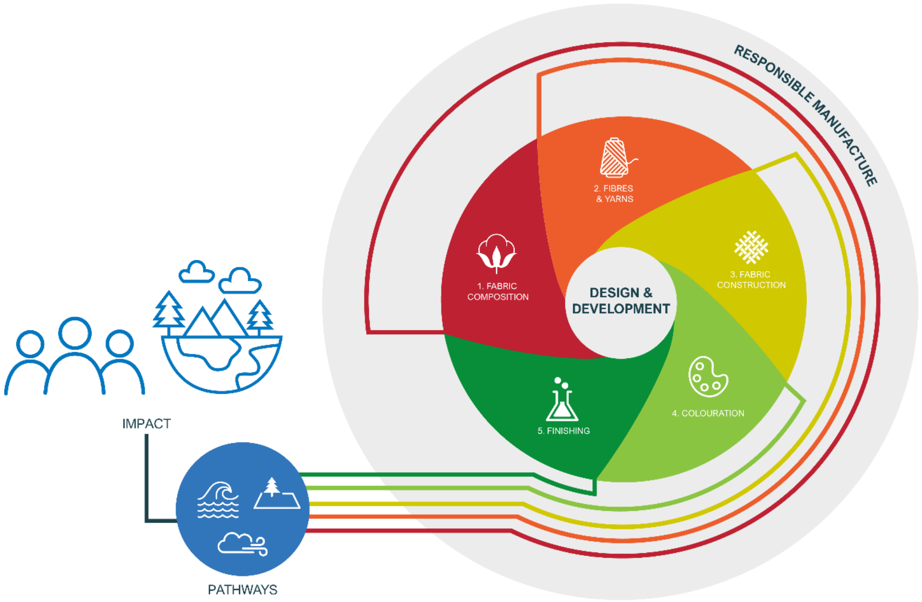

Figure 3: Microfibre pathways to the environment.

We know that all types of fabrics have a propensity to shed to some extent, but studies have found differences in the levels of microfibres released by fabrics with different structures, yarn types, compositions and finishing treatments (Periyasamy and Tehrani-Bagha, 2022). The full impact of their physical presence and toxicological impact on human and animal health are growing areas of research. Synthetic microfibres have been documented in human intestinal tracts, placental tissue, blood and lung tissue (Pauly et al., 1998; Ibrahim et al., 2021; Ragusa et al., 2021; Leslie et al., 2022), but the effect on human health is largely unknown. Observations from occupational exposure in industry showed that exposure in humans could cause inflammation of the lungs or a decrease in immune response (Athey et al., 2022). Negative health effects have been documented in a wide range of aquatic and terrestrial organisms (de Sá et al., 2018).

Although recycled polyester is considered to be a more sustainable alternative to virgin polyester, it is still not fully understood how the recycling process affects fibre fragmentation of textiles. There is some indication the recycling process could influence the levels of fibre fragmentation from garments, due to differences in the fibre properties between virgin and recycled polyester. Majumdar et al. found that recycled polyester has lower crystallinity and tensile strength than virgin polyester, and the rigidities of woven fabric increase with the incorporation of recycled polyester (Majumdar et al., 2020). Yuksekkaya et al. (2016) found that the tensile and bursting strengths were lower for recycled polyester than virgin polyester (Yuksekkaya et al., 2016).

Previous Studies

Whilst many recent studies have included recycled polyester fabrics to some extent in their studies of microfibre shedding during fabric washing (Table 1), the effect of recycled polyester itself is unclear. Details of the tested fabric and yarn properties and production parameters are often omitted from material descriptions and methodologies (Özkan and Gündoğdu, 2021). Information on the recycling process used in the production of the fabrics in the studies (mechanical or chemical) is also usually not included. Analysis of such data becomes difficult as it is often not possible to compare microfibres loss between fabrics, and it is unclear if the difference in microfibre loss is due to the presence of recycled fibres, or another variable.

Jönsson et al. (2018), found that virgin polyester fabrics released more microfibres than recycled polyester fabrics in both fleece and tricot samples (Jönsson et al., 2018). De Falco et al. (2020), found that recycled plain weave polyester released fewer fibres than virgin plain weave polyester, but no difference was found between recycled and virgin twill weave (De Falco et al., 2020). Belzagui et al. (2019) measured microfibre loss from 11 fabrics with a variety of structures and compositions. Although the recycled polyester shirt released the lowest level, the differences in fabric structures make it hard to draw conclusions on the cause (Belzagui et al., 2019). Hartline et al.

(2016) measured microfibre release from five fabrics including virgin and recycled polyester, but the results were inconclusive (Hartline et al., 2016).

Özkan and Gündoğdu, (2021) is the only study to assess fabrics made specifically for the research with the same fabric structure in both recycled and virgin polyester samples, and additionally, comparing staple and filament yarns. Fabrics made from recycled polyester in this study were found to shed, on average, 2.3 times more microfibres than those made from virgin polyester, independent of yarn type. This is suggested to be due to the shorter fibre lengths of recycled polyester and lower breaking strength, caused by the structural differences. However, this study measured microfibres by number and not by mass, so the greater number of recycled polyester fibres shed may have been due to shorter fibre fragments, yet the overall microfibre mass lost could have been the same (Özkan and Gündoğdu, 2021).

Table 1: Summary of the previous work on the release of microfibre loss during laundering from recycled polyester

Reference	Fabrics compared	Fibre count method	Microfibre loss results
Belzagui et al., 2019	Eleven garments including one recycled 100% polyester shirt	Fibre count	The recycled polyester shirt released the lowest level of microfibres.
Hartline et al., 2016	1) 100% nylon 2) 85% recycled polyester, 15% polyester 3) 63% recycled polyester, 33% polyester, 3% spandex 4) 100% polyester 5) 100% polyester	Filter mass	Inconclusive.
De Falco et al., 2020	1)Twill weave polyester; 2) Twill weave recycled polyester; 3) Plain weave polyester; 4) Plain weave recycled polyester	Fibre count	Recycled plain weave polyester released less than virgin. Recycled and virgin twill weave released the same.
Özkan and Gündoğdu, 2021	Eight fabrics: knitted 1x1 rib fabric four recycled polyester and four virgin polyester	Fibre count	Fibre loss is greater from recycled polyester, across all samples.
Jönsson et al., 2018	Six fabrics including a recycled PET fleece and a recycled PET tricot	Fibre count	Virgin polyester fleece and tricot shed more microfibres than recycled fleece and tricot.

Research Approach and Methodology

Aim

It is known that, depending on the quality of the feedstock and the recycling method, there may be a difference in fibre, yarn and fabric properties between recycled and virgin polyester, but it is not yet fully understood if or how this affects microfibre loss. Previous studies have compared recycled and virgin polyester microfibre loss but only using limited fabric types in small-scale studies.

As an independent multi stakeholder initiative, The Microfibre Consortium (TMC) called on signatories to generate and anonymously share fabric microfibre loss data. A call-to-action was issued to its brand and retailer members to submit data via The TMC Data Portal from 100% recycled and virgin polyester fabrics tested per The Microfibre Consortium Test Method.

This report outlines the analysis of the resultant data within The Microfibre Data Portal with the aim to investigate how the replacement of virgin polyester with recycled polyester affects fibre fragmentation in finished fabrics and the effect of recycling methods (chemical and mechanical).

Method

Data Sources

Data was extracted according to the following parameters from The Microfibre Data Portal, the largest fibre fragmentation database globally:

- Data submitted to the Data Portal between the dates of the 12th of March 2020 and the 1st of March 2023.
- Fabrics comprised of 100% virgin polyester or 100% recycled polyester.
- Exclusion of virgin / recycled polyester blends.

The available data was compiled from a total of 251 fabrics submitted from 36 brands and retailers. Of these, 79 were made from 100% recycled polyester fibres and 172 from 100% virgin polyester fibres. Within the recycled group, 42 fabrics were mechanically recycled, 11 chemically recycled and 26 recycled using an unknown method (Figure 4). Each fabric was tested between 8 and 24 times resulting in a total of 2,977 individual polyester test data points. The fabrics analysed had diverse fabric specifications, such as different yarn, fabric construction and / or finishing methods.

Four polyester fabrics were excluded from the dataset prior to analysis due to an indication of a testing issue, for example, an extremely high level of mass loss of the filter instead of mass gain (-3.0 g).

Figure 4: The composition of fabrics analysed, produced with virgin polyester or polyester recycled either mechanically, chemically or with an unknown method.

For further analysis, the data was subset to only include 100% polyester fabrics made from both filament yarn in a weft knit structure to compare microfibre loss from recycled and virgin fabrics with the same yarn and fabric construction, to limit the variables. In this group, 53 fabrics were made from recycled polyester and 73 from virgin polyester. The recycled group was then made up of 30 mechanically recycled fabrics, 8 chemically recycled fabrics and 15 fabrics recycled with an unknown method.

Data Analysis

Analysis was performed using Rstudio (R version 4.2.1). To compare recycled and virgin polyester, a two-sample t-test was performed. To compare mechanical, chemical and virgin polyester a one-way ANOVA was performed. Fabrics recycled with an unknown method were excluded in this part of the analysis as they could not be reliably assigned to a particular recycling group. A Tukey post-hoc test was used for group comparisons. When analysing the results of the t-test and ANOVA, a p-value of 0.05 was considered statistically significant.

In this report, the data has been visually represented using box and whisker plots as they show the spread (variability) of the data. Each small black dot represents an individual data point; around half of the data points are located within the box. The line inside the box represents the median of the data; the red circle represents the mean. The outer lines (top and bottom) of the box signify the x1.5 interquartile range; anything outside of the interquartile range could be considered an outlier.

Data Analysis Results

Fabrics were washed as per the TMC Test Method and microfibre loss was measured following filtration of the resultant wastewater. Microfibre loss is represented as a mass ratio based on the initial fabric weight in grams per kilogram (g/kg). The spread of the data is illustrated by the standard deviation.

The effect on microfibre shedding by replacing virgin polyester with recycled polyester was initially explored by comparing fabric data based on their polyester resource, regardless of individual yarn specifications and/or fabric construction. Microfibre loss of these two groups is presented in Table 2. A visual comparison of the data (Figure 5) did not reveal any clear difference between the two groups. This was supported by the outcome of the statistical analysis, which indicated there was no significant difference in microfibre loss between virgin and recycled polyester fabrics (see Appendix for results from the statistical analysis).

Table 2: Microfibre loss from all recycled and virgin polyester fabrics.

Polyester Resource	**Number of Fabrics**	**Mean Microfibre Loss (g/kg)**	**Standard Deviation**
Virgin	172	0.478	0.758
Recycled	79	0.499	0.476

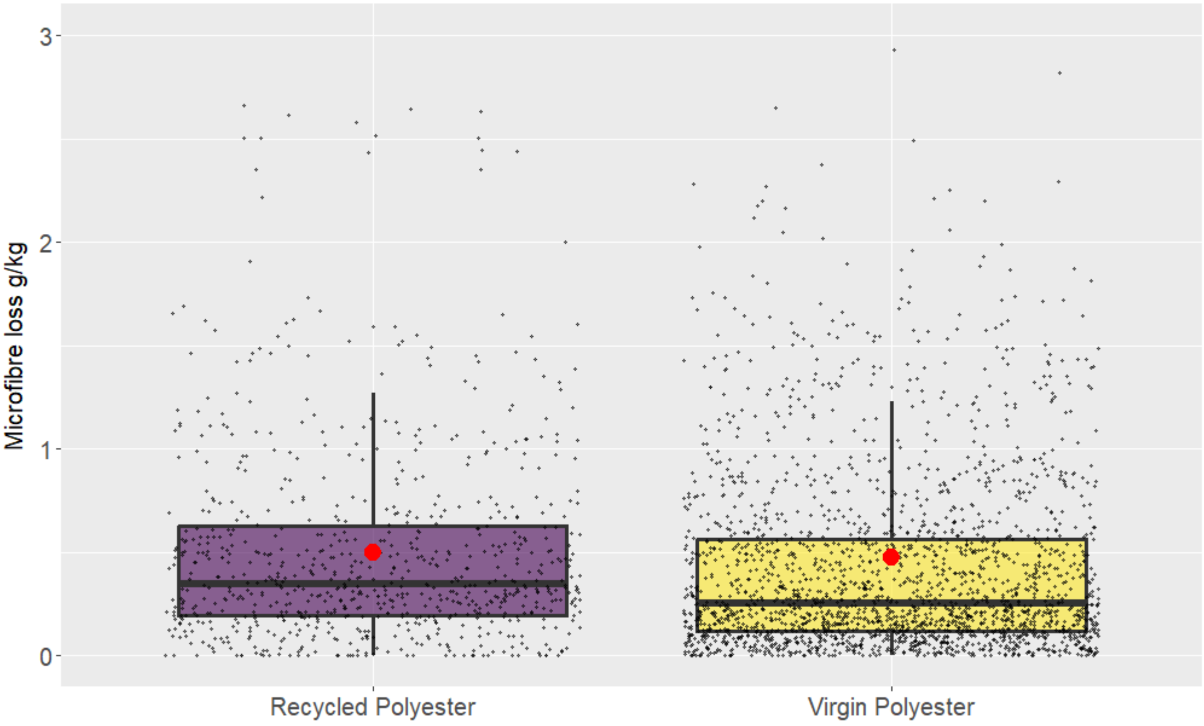

Figure 5: Box and whisker plot depicting the spread of data, indicating, visually, there is no clear difference in microfibre loss between recycled and virgin polyester fabrics.

To investigate if there was a difference in effects between mechanical and chemical recycling, recycled polyester fabrics were sub-categorised by recycling method (mechanical, chemical and virgin) (Figure 6; Table 3). A number of recycled polyester fabrics (26) that could not be assigned to a specific recycling method were categorised as 'unknown'. Chemical recycling was represented by the smallest group – just 11 fabrics, in comparison to 42 mechanically recycled and 172 virgin polyester.

Differences in the mean fibre loss between the groups are apparent in the data (Table 3), although the findings were not as straight forward as the data indicated. Chemically recycled polyester fabrics appeared to result in greater microfibre loss compared with other groups, which was supported by the statistical analysis (see Appendix 2). On further investigation, this disparity in data was caused by just one fabric that had an average microfibre loss approximately five times higher than the overall mean within all conditions (2.46 g/kg vs 0.48 g/kg). Due to the lower sample size within the group (11 fabrics), this fabric skewed the mean value. When this outlier fabric was removed from the dataset, the mean microfibre loss in the chemically recycled condition decreases from 0.76 to 0.51 g/kg, and the chemical recycling group was no longer significantly different to the mechanically recycled or virgin groups.

The chemically recycled fabric outlier can be easily identified when the data is visually represented as a box plot (Figure 6), highlighted by the cluster of data points around 2.5 g/kg. To demonstrate the effect the outlying had on the chemically recycled dataset, the dataset is also provided in absence of that one fabric. Furthermore, the group comparison test found no statistically significant difference between mechanically recycled and virgin fabrics.

Table 3: Microfibre loss from separate recycling methods and virgin polyester fabrics.

Polyester Resource	**Number of Fabrics**	**Mean Microfibre Loss (g/kg)**	**Standard Deviation**
Virgin	172	0.478	0.758
Chemical	11	0.757	0.766
Mechanical	42	0.421	0.375
Unknown	26	0.503	0.372

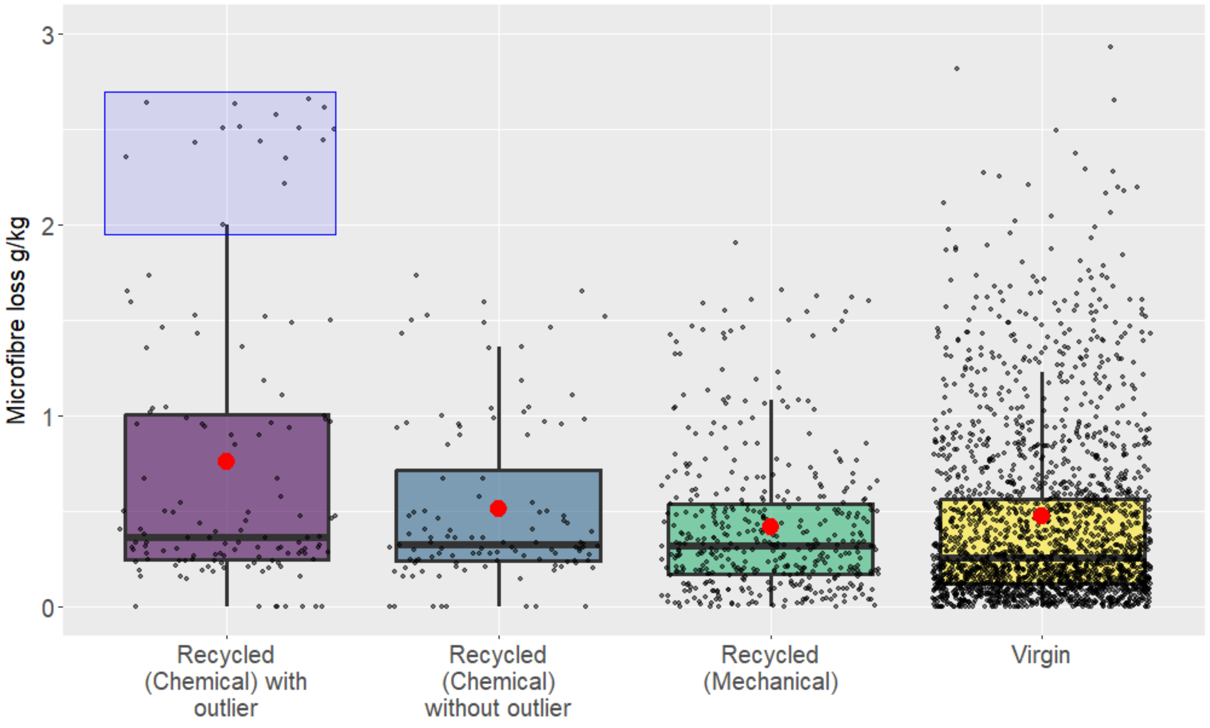

Figure 6: Box and whisker plot depicting the spread of the microfibre loss data of each recycling method and virgin polyester fabrics. The data is represented with and without the identified outlier in the chemical recycled group (highlighted in a pale blue square). In the absence of the outlier, no clear difference is observed across recycling groups.

Acknowledging there may be differences between fabrics with staple and filament yarns, and weft and warp fabric structures, fabrics were categorised based on their yarn and fabric structures to allow for a greater like-for-like comparison. The data was therefore subset to only include fabrics made from filament yarn and weft structure, as this was by far the most common combination of yarn and structure type in the dataset.

Restricting the types of fabrics included in the data set reduced the number of tested virgin polyester and recycled polyester fabrics to 73 and 53, respectively. Interestingly, this also resulted in a reduction in the spread of the data within the virgin group. Despite this, there was still no indication of recycled polyester fabrics resulting in higher fragmentation than virgin polyester fabrics (Figure 7; Table 4), further supported by the statistical output (see Appendix).

Table 4: Microfibre loss from recycled and virgin polyester fabrics made from both filament yarn and weft knit.

Polyester Resource	Yarn type	Fabric structure	Number of Fabrics	Mean microfibre loss (g/kg)	Standard Deviation
Virgin	Filament	Weft	73	0.525	0.565
Recycled	Filament	Weft	53	0.500	0.488

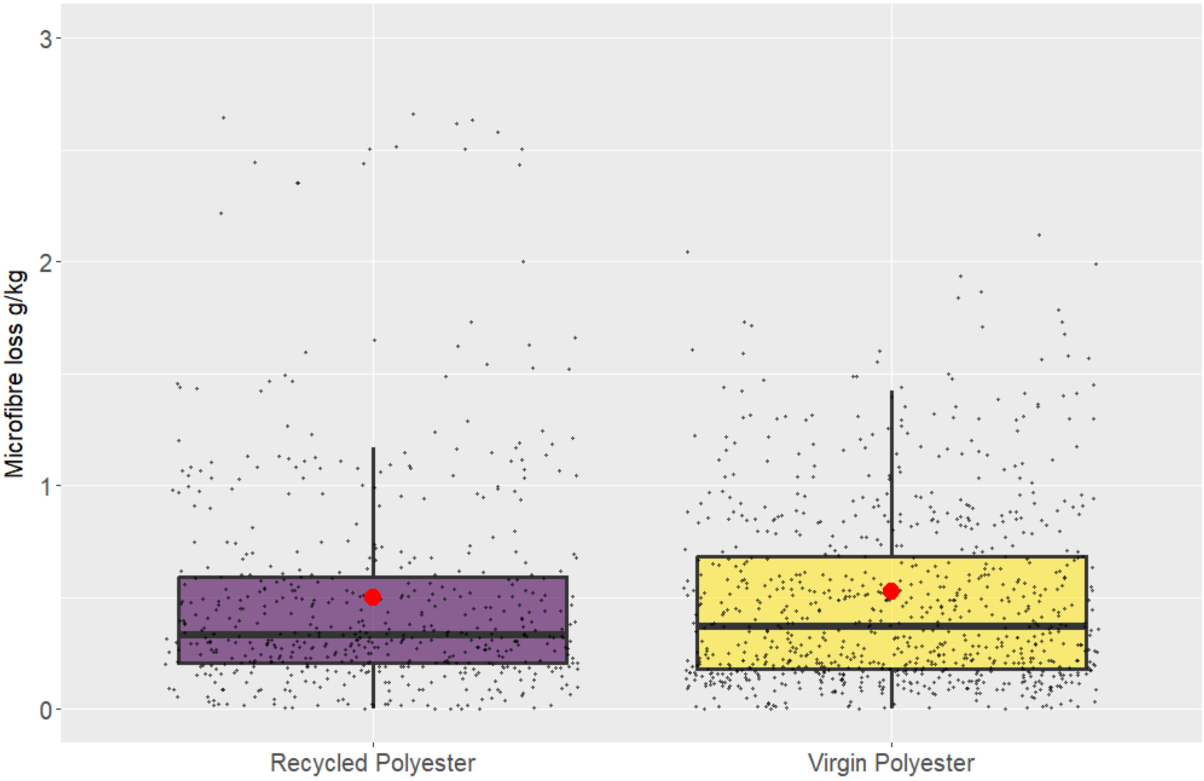

Figure 7: Box and whisker plot depicting the spread of data, indicating, visually, there is no clear difference in microfibre loss between recycled and virgin polyester fabrics made from filament yarn in a weft knit structure.

For completeness, the group containing only filament yarn and weft knit fabrics was further separated into chemical and mechanical recycling methods, and a significant difference was found (Figure 8; Table 5) (Appendix). The chemically recycled group size was further reduced to eight, which included the high outlier, affecting the results in the same manner as described above.

However, a significant difference in microfibre loss was identified between mechanically recycled fabrics and virgin fabrics. Mechanically recycled polyester fabrics, formed from filament yarns in a weft knit structure, shed significantly less microfibers than virgin polyester fabrics.

Table 5: Microfibre loss from separate recycling methods and virgin polyester fabrics made from both filament yarn and weft knit.

Polyester Resource	**Yarn type**	**Fabric structure**	**Number of Fabrics**	**Mean microfibre loss (g/kg)**	**Standard Deviation**
Virgin	Filament	Weft	73	0.525	0.565
Chemical	Filament	Weft	8	0.781	0.812
Mechanical	Filament	Weft	30	0.379	0.338
Unknown	Filament	Weft	15	0.560	0.338

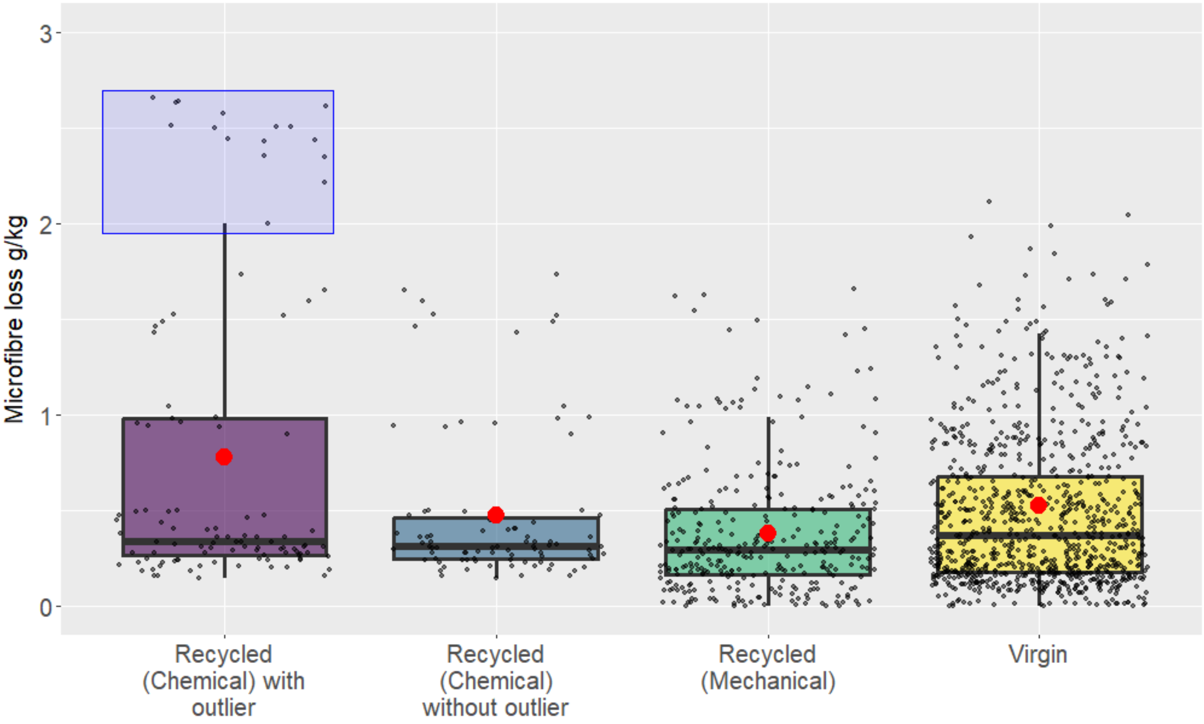

Figure 8: Box and whisker plot depicting the spread of the microfibre loss data of each recycling method and virgin polyester fabrics made from both a filament yarn and a weft knit. The data is represented with and without the identified outlier in the chemical recycled group (highlighted in a pale blue square).

Summary of Findings

As the use of recycled polyester is increasing, it is essential that all aspects of its potential environmental impact are understood. Fibre fragmentation has emerged as an important issue within the textile industry and should be considered when evaluating the sustainability credential of a product.

Of the 251 polyester fabrics tested, there was no general difference in microfibre loss between those fabrics formed from virgin polyester and those made from recycled polyester. These findings differ from those reported by Özkan and Gündoğdu (2021), who found recycled fabrics shed more than virgin fabrics.

Investigating specific recycling methods in greater detail revealed the shedding of mechanically recycled polyester fabrics to be in line with those made from virgin polyester. Although there was some indication that chemically recycled polyester fabrics shed differently to virgin polyester fabrics, the small sample size of the group and presence of one high-shedding fabric means the finding should be treated with caution. The significance of the results from the chemical recycling group is reliant on just one fabric. Thus, we would recommend more testing data is required from chemically recycled fabrics before a conclusion can be reached regarding the effect of chemical recycling on microfibre loss.

For a greater like-for-like comparison, fabrics made from filament yarn in a weft knit structure were subset from the data set. This revealed a difference between those fabrics made from mechanically recycled fabrics and virgin fabrics. The level of fibre fragmentation from mechanically recycled fabrics was lower. This finding may be surprising as the mechanical recycling process of fibres was assumed to weaken the fibres, leading to increased fragmentation. However, the finding is in line with Jönsson et al. (2018) and Belzagui et al. (2019) and to some extent, De Falco et al. (2020). In the latter study, lower fragmentation was observed from recycled polyester fabrics with a plain weave structure yet no difference was observed with a twill weave (De Falco et al. 2020). This indicates that whilst in some conditions mechanically recycled fabrics may release fewer microfibres, fabric structure may have a greater influence. Deeper research is required to firstly substantiate, and secondly, fully understand the root cause of the difference observed.

Based on the available data in The Microfibre Data Portal, there is no indication that recycled polyester results in greater fibre fragmentation when compared with its virgin counterpart. However, the findings emphasise the complex nature of fibre fragmentation, which is in line with results reported by Hazlehurst et al. (2023) who found that fibre fragmentation is driven by a combination of factors (Hazlehurst et al., 2023). The presence or absence of recycled fibres is just one of the multiple factors which need to be considered to reduce microfibre loss. These results suggest other variables may have a greater effect on fibre fragmentation than the method of polyester production.

Moreover, the findings of this study suggest that fabrics comprised of recycled polyester fibres generally do not cause increased fibre fragmentation. Nevertheless, they do not fragment less than virgin polyester. So, whilst moving from virgin polyester to recycled polyester may have its benefits, it will not in itself lead to a reduction in microfibre loss and thus, pollution. This highlights the urgent need for more work to be done to address the complex topic of fibre fragmentation if we are to determine root cause and implement change at the source.

Knowledge gaps and next steps

We were unable to reliably assess the effect of chemical recycling on fibre fragmentation, in part, due to chemically recycled polyester fabrics being less available due to the currently limited technology. As more chemically recycled polyester fabrics become available, we will call on the industry for testing of these fabrics. Better clarity on the recycling process and feedstock of fabrics would also be helpful to understand more about the effect of recycling on fibre fragmentation.

This work focused specifically on the effect of one variable only, the recycling process of polyester fibres. It is clear multiple factors affect fibre fragmentation. More understanding could be gained from a deep, holistic analysis of all fabric data within The Microfibre Consortium Data Portal to:

- assess the effect of other fabric conditions such as knit and structure type and finishing methods.
- assess how these factors interact to influence fibre fragmentation.

Appendix

Two-sample t-test of recycled and virgin polyester – all fabrics

	T	df	P
Recycled or virgin polyester	-0.921	2180	0.3571

One-way ANOVA test of different recycling types and virgin polyester – all fabrics

	df	Sum of squares	Mean square	F ratio	P
Mechanically recycled, chemically recycled or virgin polyester	2	11.3	5.671	11.18	1.46E-05

Post-hoc Tukey test of different recycling types and virgin polyester – all fabrics

	Diff	Lwr	Upr	P adj
Mechanical - chemical	-0.336	-0.504	-0.168	0.000009
Virgin - chemical	-0.280	-0.431	-0.128	0.00005
Virgin - mechanical	0.057	-0.0314	0.144	0.287

Two-sample t-test of recycled and virgin polyester – just filament and weft fabrics

	T	df	P
Recycled or virgin polyester	0.88978	1312	0.3737

ANOVA test of different recycling types and virgin polyester – just filament and weft fabrics

	df	Sum of squares	Mean square	F ratio	P
Mechanically recycled, chemically recycled or virgin polyester	2	13.2	6.600	22.24	3.2e-10

Post-hoc Tukey test of different recycling types and virgin polyester – just filament and weft fabrics

	Diff	Lwr	Upr	P adj
Mechanical - chemical	-0.402	-0.547	-0.257	<0.000001
Virgin - chemical	-0.256	-0.388	-0.123	0.0000194
Virgin - mechanical	0.146	0.062	0.230	0.0001459

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