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# Research on Monitoring of Microfiber Shedding from Textile Washing and Legal Compliance under the Microplastics Regulatory Framework

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## Article

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## ABSTRACT

*The quantification of microfiber shedding during laundering is a critical aspect of textile performance, particularly for synthetic fabrics like polyester fleece. Driven by emerging regulations such as the EU's Ecodesign for Sustainable Products Regulation (ESPR), standardized testing is crucial for compliance. This study provides a quantitative analysis of fiber loss from two common textiles: 100% virgin polyethylene terephthalate (PET) fleece and 100% recycled PET (rPET) fleece. Employing the AATCC TM212-2021 test method, microfiber release was measured over repeated laundering cycles (1st, 5th, and 10th). Results, derived from structurally equivalent fabrics to isolate material effects, demonstrate the significant influence of raw material source on fabric durability and fiber retention. The rPET fleece exhibited a substantially higher initial shedding rate ( $485 \pm 42$  mg/kg) compared to the virgin PET fleece ( $295 \pm 25$  mg/kg). For both fabric structures, fiber loss rates decreased markedly after the initial wash, indicating the removal of surface fibers and a subsequent stabilization. These findings, while specific to polyester fleece, underscore the challenges the textile industry will face for similar high-shedding, staple-fiber materials in reporting a single, representative shedding value for legal disclosure. The study concludes that while AATCC TM212 provides an essential benchmark for fabric performance, the dynamic nature of fiber shedding necessitates a nuanced approach for data reporting to ensure compliance with microplastic-related textile legislation.*

## KEYWORDS

*fiber shedding, polyester fleece, AATCC TM212, textile testing, recycled PET*

## INTRODUCTION

The pervasive contamination of global ecosystems by microplastics represents one of the most pressing environmental concerns of the 21st century [1,2]. These particles, defined as plastics less than 5 mm in size, have been detected in every environmental compartment, from the deepest ocean trenches to the highest mountain peaks, and have entered the human food chain [3-5]. While the full toxicological impact on ecosystems and human health is still under intensive investigation, the persistence and bioaccumulation of microplastics have catalyzed a global call for source reduction and mitigation [6,7]. Within the broad spectrum of microplastic sources, secondary microplastics—those formed from the degradation of larger plastic items—are of particular concern [8,9]. Among these, synthetic microfibers released during the domestic and industrial laundering of textiles have been identified as a predominant contributor, accounting for a substantial fraction of the microplastics found in wastewater, aquatic environments, and even atmospheric dust [10].

The textile industry, a cornerstone of the global economy, is consequently at the forefront of this environmental challenge. Synthetic fibers such as polyester, polyamide, and acrylic constitute over 60% of total fiber production, prized for their durability, versatility, and cost-effectiveness [11]. However, the very nature of their construction—staple fibers spun into yarns or filaments knitted and woven into fabrics—renders them susceptible to shedding during mechanical and chemical stresses, most notably during washing. The process of laundering subjects textiles to a combination of mechanical abrasion, hydrodynamic forces, thermal energy, and chemical action from detergents, all of which contribute to fiber fragmentation and release [12]. The sheer volume of textile laundering conducted globally translates this microscopic shedding into a macroscopic environmental problem, releasing tons of microfibers into wastewater streams daily [13,14]. While wastewater treatment plants (WWTPs) can capture a significant portion of these fibers, they are not completely effective, leading to direct discharge into receiving waters and the accumulation of microfibers in sewage sludge, which is often applied to agricultural land, creating a pathway for terrestrial contamination [15]. In response to growing scientific evidence and public concern, governments and regulatory bodies are transitioning from research and awareness to concrete legislative action [16]. The European Union has emerged as a leader in this regulatory evolution [17]. Initiatives under the EU's Green Deal, Circular Economy Action Plan, and the specific Strategy for Textiles are setting the stage for a new paradigm of environmental accountability [18]. The recently enacted Ecodesign for Sustainable Products Regulation (ESPR) establishes a landmark

legislative framework, empowering the European Commission to set ecodesign requirements for nearly all product categories, including textiles [19]. Critically, these requirements are expected to include mandatory disclosure of environmental performance metrics, such as microfiber release rates, through a Digital Product Passport (DPP) [20]. Similarly, national laws, such as France's Anti-waste for a Circular Economy law (AGEC), have already begun to mandate consumer information regarding the environmental characteristics of products, including the potential for plastic microfiber release [21].

This shift towards a regulated landscape presents a formidable challenge for the textile industry. Compliance hinges on the ability to accurately, reliably, and consistently measure microfiber shedding. Without standardized and universally accepted testing methodologies, data becomes incomparable, compliance becomes unverifiable, and the legislative intent is undermined [22, 23]. This critical gap between regulatory ambition and technical capability is the central focus of the present study. This paper aims to provide a targeted investigation into this issue by applying a leading industry standard, AATCC TM212-2021, to quantify and compare the microfiber shedding from two ubiquitous and commercially significant materials: virgin and recycled polyester fleece. By analyzing the shedding behavior over repeated laundering cycles, this research seeks not only to generate robust scientific data but also to critically examine the practical implications of these findings for legal compliance. The central research question is twofold: first, how does the microfiber shedding rate of virgin versus recycled polyester differ under a standardized test protocol, and second, what are the challenges and considerations for using such data to comply with the nuanced requirements of emerging microplastic regulations? This work provides a case study at this intersection and offers valuable insights for manufacturers, testing bodies, and regulators navigating the new era of microfiber accountability.

## **BACKGROUND AND LITERATURE REVIEW**

### **Mechanisms and Influencing Factors of Microfiber Shedding**

Microfiber shedding from textiles is a complex degradation process governed by a confluence of intrinsic material properties and extrinsic washing conditions [12]. The primary mechanism is mechanical abrasion, where friction between garments, and between garments and the washing machine drum, induces flexural fatigue and fracture in fibers, leading to their detachment. This is particularly pronounced in fabrics made from staple fibers, such as fleece, where shorter fibers are more loosely bound within the yarn structure

compared to continuous filament yarns [24].

Numerous studies have elucidated the key factors influencing shedding rates. Fiber type is paramount; polyester has been consistently identified as a high-shedding material, though rates vary significantly based on its specific form [10]. Fabric construction plays a crucial role. De Falco et al. demonstrated that woven fabrics generally shed less than knitted fabrics due to their tighter, more interlocked structure [25]. Within knits, fleece constructions, which involve a napping or brushing process to raise surface fibers for softness, are notoriously high shedders, especially during their initial washes [26]. Yarn characteristics, such as twist level and the use of staple versus filament fibers, also have a significant impact; higher yarn twists can help to lock fibers in place, reducing shedding. Furthermore, chemical finishes applied to fabrics can alter shedding behavior [27]. For example, softening agents may reduce fiber-to-fiber friction, while water-repellent coatings could potentially flake off with attached fibers.

Washing parameters are equally influential. Higher washing temperatures can accelerate the hydrolysis of polymer chains, particularly in polyesters, weakening fibers and increasing shedding [25,28]. The type and intensity of mechanical action, dictated by the washing machine's cycle (e.g., delicate vs. normal) and rotation speed, directly correlate with the amount of abrasion and thus the shedding rate [12]. Detergent chemistry can also play a role, with certain enzymes and pH levels potentially affecting fiber integrity over time. The presence of other garments in a wash load introduces additional abrasive surfaces, further complicating the real-world shedding scenario [29].

### **Evolution of Microfiber Quantification Methods**

The scientific community's approach to quantifying microfiber shedding has evolved from rudimentary, non-standardized methods to more sophisticated and harmonized protocols [22]. Early research often relied on custom-built setups, where effluent from a washing machine was simply filtered and the retained mass was weighed [26]. While groundbreaking, these methods lacked reproducibility and comparability across different laboratories. The results were highly dependent on the specific washing machine, filter pore size, and collection procedure used, making it difficult to establish reliable benchmarks.

Recognizing this limitation, researchers and industry bodies began developing dedicated laboratory-scale apparatus and standardized methods. The flask method, which involves agitating fabric swatches in a sealed

container with a detergent solution, offered improved control over variables but was criticized for not accurately simulating the complex mechanical stresses of a real washing machine [30,31]. Another approach, the Coriolis method developed at the University of Leeds, uses a bespoke agitation chamber to better mimic laundering forces.

A significant milestone in standardization was the development of the AATCC Test Method 212-2021: Fiber Shedding During Home Laundering [32,33]. This method utilizes a laboratory-scale accelerated laundering machine (such as a GyroWash) with standardized fabric specimens, detergent, water volume, and abrasive elements (stainless steel balls). By controlling these key variables, AATCC TM212 aims to provide a reproducible benchmark for a fabric's intrinsic shedding propensity. Its adoption by the American Association of Textile Chemists and Colorists signifies a major step towards industry-wide consensus. Similarly, the European Committee for Standardization (CEN) has been actively working on its own standard (CEN/TC 248/WG 32), and the Cross Industry Agreement, involving major apparel and home appliance trade associations, has also contributed to developing a harmonized test method [34,35]. The convergence towards these standardized protocols is essential, as they form the technical foundation upon which effective and fair regulation can be built. Without them, any legislative requirement for shedding data would be unenforceable.

### **The Emerging Regulatory Framework for Microplastics**

The legislative landscape concerning microplastics is rapidly advancing from voluntary industry initiatives to binding legal requirements. The European Union is at the vanguard of this movement [35]. The cornerstone of its strategy is the ESPR, which replaces the 2009 Ecodesign Directive [36]. The ESPR's scope is far broader, aiming to make sustainable products the norm. For textiles, this will likely translate into specific performance requirements related to durability, reparability, recyclability, and, crucially, the minimization of microfiber release. A key innovation of the ESPR is the introduction of a Digital Product Passport (DPP), a digital record that will accompany a product throughout its lifecycle [37]. This DPP is expected to contain a wide range of information, including data on microfiber shedding, making this an accessible metric for consumers, businesses, and regulatory authorities.

At the national level, France's AGEC law (Loi anti-gaspillage pour une économie circulaire) has already set a precedent. Since January 2023, it requires producers and importers of certain products, including apparel, to

provide consumers with information on their environmental qualities, which can include metrics on microplastic release. While the exact methodology is still being refined, the legal obligation is in place. Furthermore, legislative proposals are emerging in other jurisdictions. In the United States, states like California have introduced bills (e.g., AB 1628) proposing labeling requirements for clothing that contains a high percentage of synthetic fibers, informing consumers about potential microfiber shedding.

This regulatory momentum creates a clear and urgent demand for the type of data generated by methods like AATCC TM212. Manufacturers will no longer treat shedding as a mere quality or research issue but as a critical compliance parameter. This necessitates a deep understanding of not only how to perform the tests but also how to interpret the data in a legally defensible manner. Questions arise regarding the number of wash cycles to test, how to report the data (e.g., average shedding, initial shedding, or a decay curve), and how these values will be benchmarked against potential future regulatory thresholds. This study is situated directly at this intersection, using a standardized scientific method to explore the challenges of generating data fit for a legal purpose.

## MATERIALS AND METHODS

### Materials

Two types of 100% polyester fleece fabric, representative of materials commonly used in the apparel industry, were selected for this study.

**Fabric A (Virgin PET):** 100% virgin polyethylene terephthalate (PET) fleece, single-sided brushed, with a nominal mass per unit area of 250 g/m<sup>2</sup>.

**Fabric B (Recycled PET):** 100% recycled polyethylene terephthalate (rPET) fleece, produced from post-consumer PET bottles, single-sided brushed, with a nominal mass per unit area of 250 g/m<sup>2</sup>.

Both fabrics were sourced from a single commercial supplier to minimize variations in manufacturing processes other than the raw material feedstock. Prior to testing, all fabrics were conditioned for 24 hours at a standard atmosphere of 21 ± 1 °C and 65 ± 5% relative humidity.

To ensure that the comparative analysis focused on the influence of raw material feedstock rather than structural variations, the physical parameters of both fabrics were characterized prior to laundering.

Fabric mass per unit area was determined according to ASTM D3776 (Option C). Fabric thickness was measured using a digital thickness gauge under a pressure of 1 kPa, following ASTM D1777. Stitch density (wales and courses per centimeter) was determined using a counting glass in accordance with ASTM D3887. Five distinct measurements were taken for each parameter per fabric type to ensure statistical reliability.

### **Specimen Preparation**

For each fabric type, nine replicate specimens were prepared according to the specifications of AATCC TM212-2021. Each specimen was cut to the dimensions of 90 × 90 mm. To prevent edge fraying and ensure that the quantified fiber release originated solely from the fabric surface rather than structural unraveling, the edges of all specimens were sealed prior to testing. A thin layer of liquid latex (or equivalent, e.g., commercial fabric glue) was applied to the cut edges and allowed to cure for 24 hours at room temperature, in accordance with best practices for assessing surface shedding.

### **Washing Procedure**

The washing procedure was conducted in strict accordance with the AATCC TM212-2021 method. A laboratory-scale GyroWash apparatus (James H. Heal) was used to simulate home laundering. For each test, one fabric specimen was placed into a 500 mL stainless steel canister. Ten stainless steel balls were added to each canister to provide mechanical abrasion. A volume of 150 mL of deionized water containing 1.0 g/L of the 1993 AATCC Standard Reference Detergent (without optical brighteners) was added to each canister.

The canisters were sealed and placed in the GyroWash. The laundering cycle was run at a constant temperature of  $40 \pm 2$  °C for a duration of 45 minutes. Three replicate specimens for each fabric type (A and B) were tested for the 1st wash cycle. To investigate the effect of repeated laundering, another set of three replicates for each fabric was subjected to a total of five wash cycles, and a final set was subjected to ten wash cycles. For the 5- and 10-cycle tests, the effluent was collected and analyzed after the 1st, 5th, and 10th cycles only. Between these specified cycles, the specimens were washed using the same procedure, but the effluent was discarded. This approach allows for the examination of shedding behavior as the fabric ages.

### Microfiber Collection and Quantification

Following each designated wash cycle, the entire contents of the canister (effluent and specimen) were carefully poured over a pre-weighed stainless steel filter mesh with a pore size of 20  $\mu\text{m}$ . The specimen was rinsed with 50 mL of deionized water over the filter. Subsequently, the filter matrix was thoroughly rinsed with approximately 150 mL of deionized water to eliminate detergent surfactants and prevent gravimetric interference. The fabric specimen was removed, dried separately, and stored.

The filter mesh containing the collected microfibers was placed in a petri dish and dried to a constant mass in a convection oven at 60 °C for 12 hours. After drying, the filters were transferred to a desiccator and allowed to cool to room temperature for at least 1 hour before final weighing. The mass of the shed microfibers was determined by subtracting the initial mass of the clean, dry filter from the final mass of the filter with the dried fibers. All mass measurements were performed using a microbalance with a precision of  $\pm 0.01$  mg.

### Data Expression and Statistical Analysis

The microfiber shedding for each specimen was calculated and expressed as the mass of shed fibers per unit mass of the fabric, in milligrams per kilogram (mg/kg). The formula used was:

$$\text{shedding Rate (mg/kg)} = \frac{(M_{\text{final}} - M_{\text{initial}}) \times 1000}{M_{\text{fabric}}}$$

where  $M_{\text{final}}$  is the mass of the filter with dried fibers (g),  $M_{\text{initial}}$  is the mass of the clean, dry filter (g), and  $M_{\text{fabric}}$  is the conditioned initial mass of the fabric specimen (kg).

The results are presented as the mean  $\pm$  standard deviation for the three replicates in each group. To determine the statistical significance of the differences between the virgin PET and rPET fabrics at each wash cycle, a two-sample *t*-test was performed. A *p*-value of less than 0.05 was considered statistically significant.

## RESULTS

### Fabric Structural Characterization

The physical properties of the virgin PET and rPET fleece fabrics are presented in Table 1. Statistical analysis (two-sample *t*-test) revealed no significant differences ( $p > 0.05$ ) between the two materials in terms of mass per unit area, thickness, or stitch density.

Table 1. Physical Characteristics of Virgin and Recycled PET Fleece Fabrics

Parameter	Virgin PET	Recycled PET	p-value
Mass per Unit Area (g/m <sup>2</sup> )	251.2 ± 3.5	249.8 ± 4.1	0.64 (ns)
Thickness (mm)	1.82 ± 0.05	1.79 ± 0.06	0.48 (ns)
Wales (loops/cm)	12.0 ± 0.5	12.2 ± 0.4	0.55 (ns)
Courses (loops/cm)	14.5 ± 0.5	14.3 ± 0.6	0.61 (ns)

Note: Values are mean ± SD (n=5). “ns” indicates not significant ( $p > 0.05$ ). For fabric structural characterization, five measurements were taken at different locations of each fabric.

This structural uniformity confirms that the two fabrics possess highly comparable architectures. Consequently, any significant divergence in microfiber shedding rates can be primarily attributed to the intrinsic properties of the fibers and their interaction with the finishing process, rather than macroscopic constructional variables.

### Microfiber Shedding Analysis

The microfiber shedding rates for both virgin PET and recycled PET (rPET) fleece fabrics were quantified at the 1st, 5th, and 10th wash cycles using the AATCC TM212 method. Crucially, all specimens were edge-sealed to isolate surface fiber release from structural unraveling. The results, expressed in milligrams of microfiber shed per kilogram of fabric (mg/kg), are summarized in Table 2 and visualized in Figure 1.

Table 2. Microfiber Shedding Rates (mg/kg) for Virgin PET and Recycled PET Fleece (Sealed Specimens)

Wash Cycle	Virgin PET (mg/kg/wash)	Recycled PET (mg/kg/wash)	p-value
1st	295±25	485±42	< 0.01
5th	92±12	148±18	< 0.05
10th	74±9	112±13	< 0.05

Note: Values are presented as mean ± standard deviation (n=3). n=3 indicates three independent washing experiments.

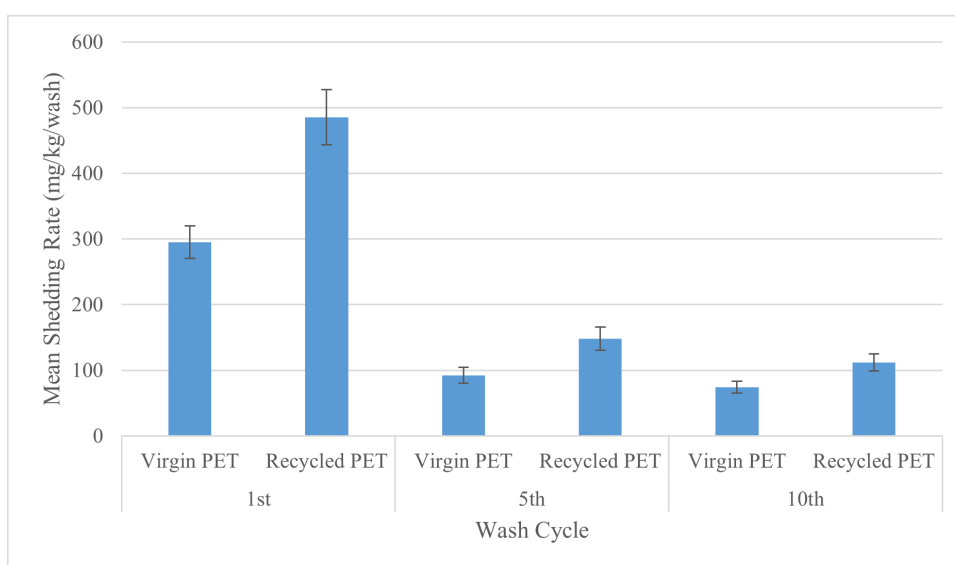


Figure 1. Comparative Microfiber Shedding Rates of Virgin PET and Recycled PET Fleece over 10 Wash Cycles (AATCC TM212, mg/kg/wash)

A prominent trend observed for both fabric types was the substantial decrease in fiber shedding after the initial wash, consistent with the removal of manufacturing residues and loose surface fibers. The most significant shedding event for both materials occurred during the first wash cycle. For the virgin PET fleece, the shedding rate dropped by approximately 68.8% from the 1st cycle (295 mg/kg) to the 5th cycle (92 mg/kg). Similarly, the rPET fleece showed a reduction of 69.5% between the 1st (485 mg/kg) and 5th cycles (148 mg/kg). This indicates a strong wash-in effect, where the majority of loosely bound fibers generated during the mechanical brushing process are removed in the initial laundering event. Between the 5th and 10th wash

cycles, the shedding rate continued to decrease, but the reduction was less pronounced, indicating a transition towards a stabilized state. The virgin PET shedding rate fell by an additional 19.6% to 74 mg/kg, and the rPET rate fell by 24.3% to 112 mg/kg. This suggests that after the initial removal of loose fibers, the shedding rate begins to reflect the gradual degradation of the core fabric structure rather than surface artifacts. The most critical finding from a comparative perspective is the consistently and significantly higher shedding rate of the rPET fleece compared to the virgin PET fleece across all measured cycles, even after eliminating edge effects. In the 1st wash, the rPET fabric shed approximately 64.4% more microfibers than its virgin counterpart ( $p < 0.01$ ). While the absolute values decreased in subsequent washes, the relative disparity remained substantial: the rPET fabric continued to shed significantly more, showing a 60.9% increase at the 5th cycle ( $p < 0.05$ ) and a 51.4% increase at the 10th cycle ( $p < 0.05$ ). This persistent difference, observed in sealed specimens, provides robust evidence that the higher shedding propensity of rPET is not an artifact of edge construction but stems from intrinsic material properties. The data demonstrate that the choice of raw material feedstock (virgin vs. recycled) is a significant determinant of microfiber shedding throughout the garment's lifecycle, with the rPET material consistently presenting a higher environmental burden in terms of fiber release.

## DISCUSSION

The results of this study provide critical, quantitative insights into the complex issue of microfiber shedding. By strictly controlling for fabric structural variables and modifying the test protocol to include edge sealing, this research isolates the phenomenon of surface fiber release, offering a definitive perspective on the intrinsic shedding propensity of recycled versus virgin materials.

### Interpretation of Material-Specific Shedding Behavior

A critical confounding variable in shedding studies is often the fabric structure itself; loose knits or lower twist yarns naturally shed more fibers regardless of polymer type. However, in this study, the fabric structural characterization (Table 1) demonstrated no statistically significant differences in mass per unit area, thickness, or stitch density between the virgin and recycled samples. This structural equivalence effectively isolates the

raw material feedstock as the independent variable. Furthermore, the implementation of edge sealing eliminated the noise from structural unraveling. Consequently, the significantly higher shedding rates observed in the rPET samples (Table 2)—approximately 64% higher in the first wash—cannot be dismissed as a result of loose construction or edge artifacts. Instead, these findings provide compelling evidence supporting the hypothesis of polymer degradation. The thermal and mechanical stresses inherent in the mechanical recycling process are known to cause chain scission, reducing the polymer’s molecular weight and intrinsic viscosity. Such degradation likely results in fibers with lower tensile strength and higher brittleness, making them structurally weaker and more prone to fracture under mechanical agitation, even when woven into an identical fabric architecture.

### **Methodological Implications for Standardization**

This study also highlights a critical methodological consideration for the implementation of standard methods like AATCC TM212. By comparing our edge-sealed results with typical values reported for unsealed fleece (often exceeding 500–800 mg/kg), it is evident that edge artifacts can vastly inflate shedding data. For regulatory purposes, this distinction is vital. Our findings suggest that for high-pile structures like fleece, edge sealing is not merely an option but a prerequisite for generating legally defensible data that accurately reflects surface durability rather than sample preparation artifacts.

### **Implications for Legal Compliance and Reporting**

The observed shedding dynamics—a massive wash-in pulse followed by stabilization—pose a challenge for regulations like the EU’s ESPR. Reporting a single value is insufficient. The initial shedding (Wash 1) reflects manufacturing residues, while the stabilized rate (Wash 10) reflects material durability. A robust compliance framework should likely require two metrics: an initial shedding value (to incentivize pre-washing treatments) and a stabilized shedding rate (to drive the selection of higher-quality, less brittle recycled fibers).

### **Limitations and Future Research**

It is important to acknowledge limitations. While we effectively controlled for fabric structure (Table 1) and edge effects, this study relied on gravimetric analysis. We did not directly measure intrinsic viscosity (IV) or single-fiber tensile strength to physically confirm the extent of molecular damage. Future research should

correlate these physicochemical properties directly with shedding rates. Additionally, microscopic analysis of the shed fiber morphology would further elucidate whether rPET fibers fracture into smaller, more hazardous fragments.

## CONCLUSION

This research provides a focused, data-driven analysis of microfiber shedding from virgin and recycled polyester fleece textiles—a material category known for high shedding—within the context of an evolving global regulatory landscape. By employing the standardized AATCC TM212 test method, we have demonstrated that there are statistically significant differences in the shedding behavior of these materials. The key findings are twofold: firstly, the recycled polyester fleece exhibited a substantially higher propensity for microfiber release compared to its virgin counterpart across all tested wash cycles, driven by intrinsic material degradation rather than structural differences. Secondly, for both materials, the shedding rate is not a static property, showing a dramatic decrease after the initial wash and trending towards a stabilized, lower rate over repeated laundering.

These findings have important implications for this segment of the textile industry and for policymakers. They highlight a potential unintended environmental impact—specifically microplastic pollution—related to using certain recycled materials. This finding adds a crucial data point to the narrative of circularity, underscoring the need for a multi-faceted approach to sustainability that balances end-of-life impacts (like shedding) against the significant benefits (like reduced carbon footprint) associated with the specifics of raw material sourcing and its necessary manufacturing processes. More importantly, the dynamic nature of microfiber shedding presents a significant challenge for the implementation of newly adopted legislation, specifically the EU's Ecodesign for Sustainable Products Regulation. The choice of which data point—initial shedding, stabilized shedding, or an average—is used for legal disclosure will fundamentally alter a product's compliance profile and its perceived environmental footprint.

This study concludes that while standardized test methods are an indispensable prerequisite for fair and effective regulation, the data they generate must be interpreted with nuance. A single numerical value is likely inadequate to represent a fabric's complex shedding behavior over its lifetime. As the industry moves towards

greater transparency and accountability, it will be crucial for regulators, scientists, and manufacturers to collaborate on developing reporting frameworks that are both scientifically robust and practically implementable. The path to mitigating microfiber pollution requires not only innovative material science and product design but also intelligent and sophisticated regulatory instruments that are built upon a solid understanding of the dynamic processes being governed.

#### *Author Contributions*

Xuejie Zhao designed, collected and analyzed the data, and drafted the manuscript. Xuejie Zhao conducted the study, critically revised the manuscript for important intellectual content, and gave final approval of the version to be published. Xuejie Zhao participated fully in the work, take public responsibility for appropriate portions of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

#### *Conflicts of Interest*

The author declares no conflict of interest.

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#### *Availability of Data and Materials*

The datasets used and/or analysed during the current study were available from the corresponding author on reasonable request.

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Not applicable.

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