Fiber Fragment Pollution—Pathways to Mitigation

By Kilara Le

In the last seven years, the impact of fiber fragment pollution has garnered attention—with efforts to quantify it and research on how to mitigate its effects. These fiber fragments have traversed and invaded the ecosystems of the globe. Blown in by tradewinds and entangled in lichens at the tops of the highest mountains or carried by currents into the stomachs of creatures lurking in deep sea trenches, fiber fragments have ensured that if we had any doubt about the connectivity of our ecosystems, they have been dispelled. Fiber fragment pollution is one of the manmade things that are here to stay with us forever, tiny fragments of our textiles that may very well never biodegrade.

DEFINING FIBER FRAGMENTS

Though they are often talked about under the broad umbrella of “microplastics,” or “microfibers,” in research studies a distinction has been made between microplastics versus fiber fragments based on their origin and physically identifying features. There is a difference noted between small fragments of solid plastic and small fragments of fibers, both of which now exist and continue to accumulate in the environment, often side by side.

Microplastics break off from larger pieces of plastic objects. They are part of a degradation process, but don’t actually biodegrade into biologically reusable elements and minerals, they just become smaller as they break apart. The exact size of a microplastic particle isn’t concretely defined, but under 5 mm is a commonly used definition. This includes the varying shapes it is found in, such as spheres, flakes, or fragments and fibers.

Fiber fragments have a linear form and come from textile products. The term “fiber fragment” has been coined to specifically address the shedding of small pieces of fiber—that are less than 5 mm -100 micrometers (µm) long—from fabric and to distinguish it from commercially-named “microfiber” fabrics, which may or may not produce fiber fragmentation. It’s important to note that a commercially produced *microfiber*, which has a linear density of 1 denier to .3 denier, is different from a fiber fragment.

Currently, fragments that have a length greater than their diameter (roughly, either 1.5 orders of magnitude or with a length to diameter ratio greater than 100) and have broken off of a textile material are considered “fiber fragments.” Although fiber fragments are often spoken about as a type of microplastic, fiber fragments can be from a synthetic polymer (such as polyester or nylon), a natural fiber (such as cotton or wool), or a semi-synthetic (such as rayon that is chemically processed from wood pulp).

Fiber fragments are released during laundering, into wastewater from washing machines, and into the air from clothes dryers, and by daily use in the cases of items like clothing, home textiles, and tires.

“Based on research studies around the globe, wastewater effluents (i.e., water after wastewater treatment) often contain a large amount of microplastics in which microplastic fibers are the dominant form of microplastics,” says Kenneth Mei Yee Leung, chair professor and acting head of the Chemistry Department at the City University of Hong Kong, “Microplastic fibers are also commonly found in storm waters (i.e., surface runoff waters) and can also occur in the atmosphere and then precipitate and sink to the aquatic environment.”

Figuring out how to quantify and then minimize fiber fragmentation is one thing, but figuring out the impact of these now ubiquitous fibers and how to capture them before they make it into the wider environment is another.

DETERMINING THE IMPACT

The sheer degree to which we now find fragmented fibers and microplastics around us is staggering. It is estimated that we, as humans, are consuming 5 grams, an amount equal to the weight of a credit card’s worth of microplastics and fibers, each week. To determine the true impact from these fiber fragments globally, scientists, manufacturers, brands, and retailers have been looking for them, or unwittingly finding them, as part of their research projects. It’s not just humans who are inadvertently consuming these particles.

Water, whether from a wastewater treatment plant or storm drain, flows into a river which eventually runs back into the ocean. The estuaries, where the land meets the sea, are the first point of impact.

“An estuary is where river waters meet the sea, and the waterways entering the estuary will carry [fiber fragments] from sewage effluent and storm water,” notes Leung.

Leung is also the director of State Key Laboratory of Marine Pollution (SKLMP) at City University of Hong Kong, and the principal scientist at the Global Estuaries Monitoring Programme (GEM) where he and other scientists are researching the impacts of pollution on marine

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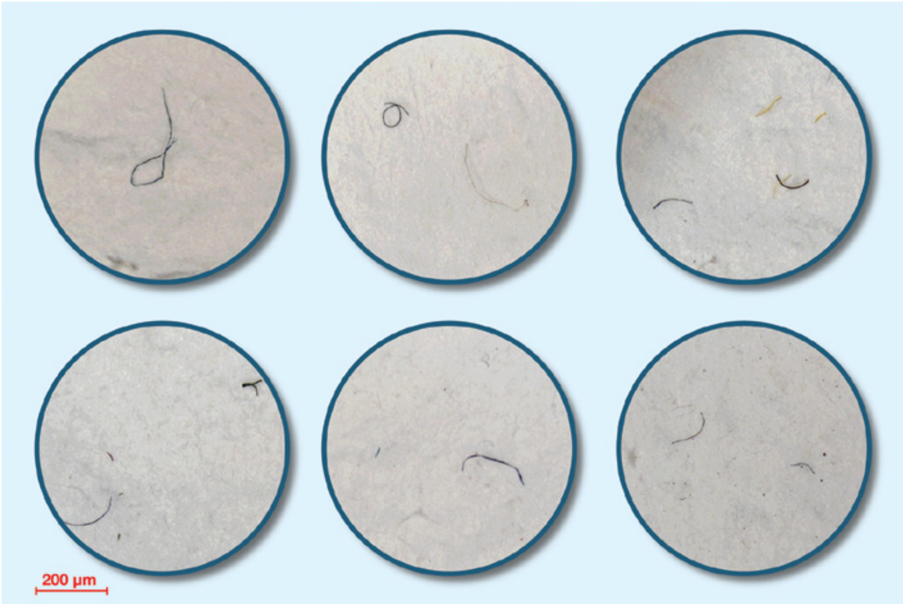
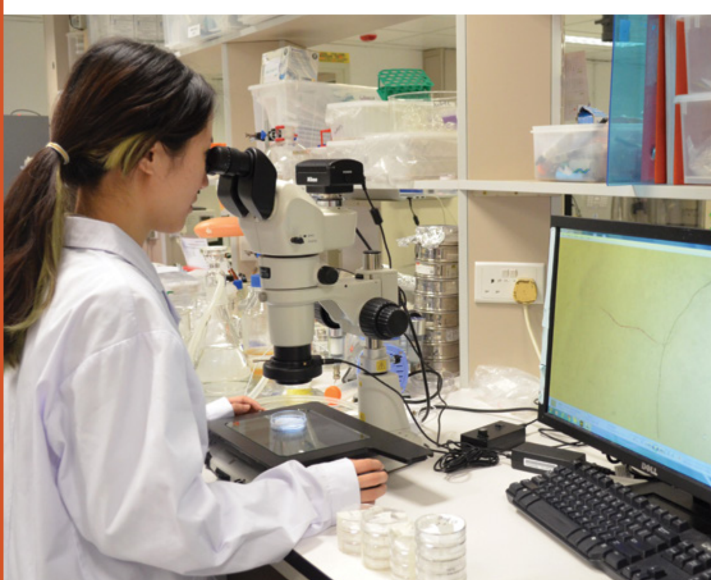


Typical microfibers released from tumble dryer.
CREDIT: KENNETH MEI YEE LEUNG



PhD student, Sunny Tao studying microfibers using a stereomicroscope at the State Key Laboratory of Marine Pollution.
CREDIT: KENNETH MEI YEE LEUNG

life and its ecosystems. He explains that the impact of fiber fragments on marine organisms depends on the concentration of them in their environment.

"If there were a low concentration of [fiber fragments], their negative impacts could be negligible. However, when their concentration is high, marine animals like copepods, isopods, mussels, oysters, barnacles, sea anemones, corals, and so on, can mistakenly ingest them; the ingested [fiber fragments] could accumulate in their gut, causing reduction of food intake and leading to weight loss; in severe cases, the reproduction of the organisms can be impaired and reduced, and some organisms may die due to ingestion of too many [fiber fragments]," states Leung. He adds that, "In our recent study (SKLMP), we showed that marine copepods exposed to elevated level of [fiber fragments], exhibited slower growth with 20% reduction of fecundity."

While organisms like fish are eaten more for their meat and their digestive systems removed, mussels and oysters are two organisms that humans ingest whole. Conclusive studies on the effects of fiber fragments on humans are lacking. We don't yet know, for instance, if they accumulate in certain places in the body, or pass through the barriers of the human body's systems, and what the effects of them in our bodies are.

Many, if not most, fabrics have some kind of chemical finish applied to them to impart a characteristic such as softness, reduced wrinkling, or oil and water repellency. Further studies are needed to determine the effect of finishes and dyes on fiber fragment degradability and chemical transmutation in the wider environment.

"In addition, microplastic (sic) fibers might be conditioned with other harmful chemicals like plasticizers," says Leung, "and they could also adsorb and absorb other synthetic organic chemical contaminants. These chemicals may be released into the marine environment and in the gut of the marine organisms, causing additional harm."

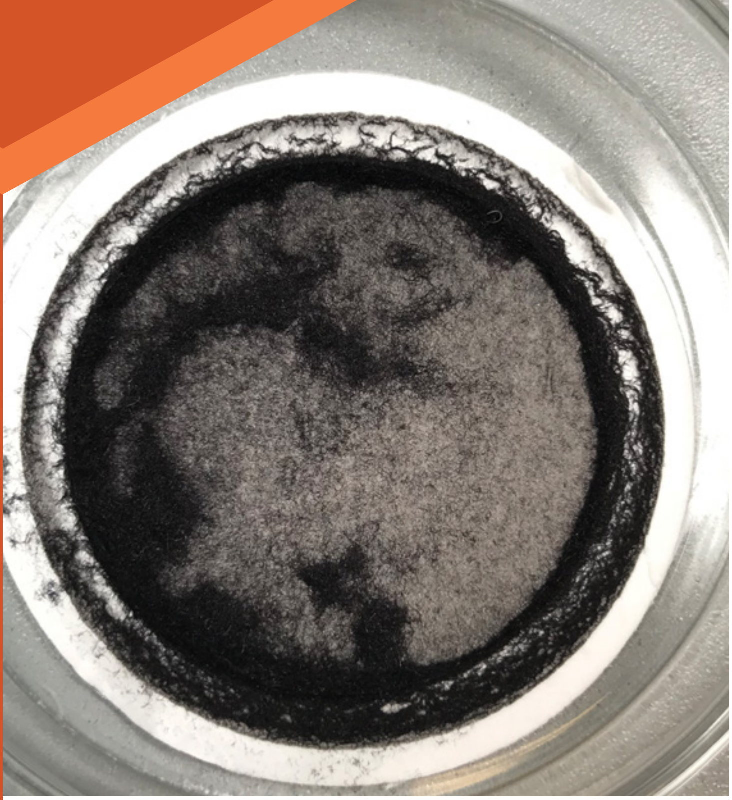
According to The Microfibre Consortium (TMC), an organization that aims 'to connect academic research with the textile supply chain for the greater good of our ecosystems', "Studies have shown quantities of [fiber fragments] released to air during tumble drying are comparable to the levels lost to waste water during washing." This is partly due to, "vented dryers releasing warm air directly to the external environment, and with it, [fiber fragments] from the clothing they dry." Although there are vent-less dryers available, both types of dryers contain lint filters, with varying degrees of efficacy.

Knowing how much a fiber or fabric sheds is critical to determining its potential to disperse across the environment. Multiple test methods have been created by organizations to quantify the number of fiber fragments released during washing of fabrics.

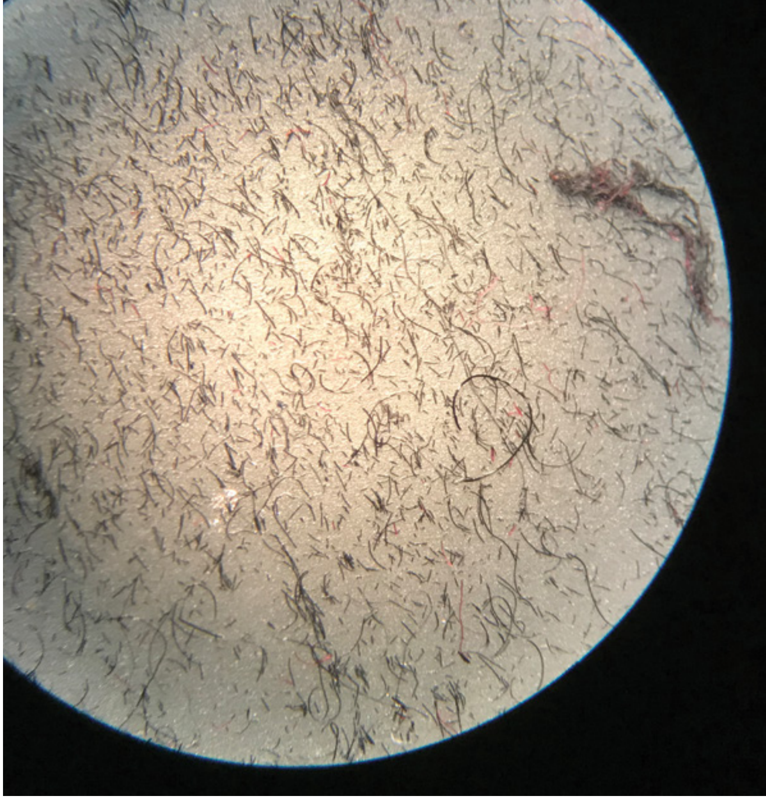
AATCC released AATCC TM212, Fiber Fragment Release During Home Laundering, in 2021 which, according to Heather Elliot, product integrity manager at Smartwool—and former chair of the RA100 Global Sustainability committee that worked to create the test method—is intended as a way "to measure fabrics against each other to see what kinds of parameters can be adjusted during production to create fabrics that shed less in a [home laundering] setting." As each washing machine, load, detergent, and water source can differ wildly, TM212, "was never meant to see how many fibers one fabric/garment will shed in the actual, real-life washing scenario," according to Elliot.

The Microfibre Consortium (TMC) created the TMC test method "focusing on the quantification of fiber release from fabrics during domestic laundering." "The TMC test method has been developed through the collaborative relationship between The University of Leeds, European Outdoor Group, and The Microfibre Consortium, along with the larger stakeholder network using ISO 105-C06 at its core," states TMC. To enable

Suspended fibers in water in vacuum filtration funnel.
CREDIT: HEATHER ELLIOT



Fibers captured on filter after test.
CREDIT: HEATHER ELLIOT



Fibers captured on filter after test under microscope.
CREDIT: HEATHER ELLIOT

wide accessibility, it was "developed to use standard lab equipment and provide accurate comparable data, in a manner that can be scaled commercially across a range of laboratory facilities."

Hohenstein has their own Dynamic Image Analysis (DIA) test for quantification of fiber release and fiber length distribution and there are other test methods such as CEN/TC 248/WG 37 and ISO/TC 38/WG 34 for microplastics from textile sources. All of these organizations are working collaboratively to enable industry to quantify fiber fragmentation and for manufacturers to take proactive action to minimize the impact of their textile products.

Brands and retailers are working with testing labs and fabric manufacturers to ramp up their testing of existing and potential fabrics to determine ways to reduce levels of fiber fragmentation at its origin.

REDUCING THE IMPACT

"The ideal solution to reduce fragmented fibre (sic) pollution is to instead stop it at the source during design and development or at manufacturing," states TMC. Key to this is testing, which can help to determine yarn, fabric construction, and finishing technique combinations that minimize fragmentation.

Elliot is keen to dispel some common assumptions regarding fragmentation based on types of fiber and fabric construction. "In research I have done, I will say that fleece can shed less than tee shirt material. So, it all depends on the type of fiber, as well as the strength of the fiber to withstand the wear and tear of washing, drying, and wearing. Just because fleece is brushed doesn't mean that it's going to shed more than an unbrushed fabric." This means that testing and sharing this data is critical to reduction of fiber fragmentation.

To reduce fiber fragment release into wastewater via washing machines, "there is now a range of filters available, with varying efficiencies and functionality," notes TMC.

"Given that microplastic fibres (sic) are predominant in sewage influent and effluent, we should remove them from washing machines and tumble dryers by installation of a simple, yet effective filtration system," states Leung. "For instance, the end of the drainage pipe (or duct) from the washing machines can be placed with a filter bag or a 3D-printed filter that can effectively remove most of the fiber fragments." He also suggests that the mesh filter inside clothes dryers can be made finer or a similar filter be placed in the vent duct to capture more fibers.

TMC notes that, "one issue with these types of technologies is the disposal of the collected fibres (sic)." For washing machine filters, "some options currently require the user to return the full filter cartridge to the manufacturer for recycling, and to replace it with a new filter," says TMC, but "this process creates additional cost, waste, and emissions."

German non-profit, Wasser 3.0 has created methods to remove fiber fragments and microplastics from wastewater, allowing the extracted materials to be disposed of properly or, ideally, reused.

Even identifying what type of fiber fragments are uncovered in research projects is a challenge due to the size and the breadth of fiber types and, unfortunately, "the technology to recycle mixed fiber fragments on a large scale does not currently exist," notes TMC. They add that if these mixed fibers are disposed of with municipal waste there is the potential, "for fiber fragments to eventually re-enter the environment."

"I think the best thing people can do is buy less or buy used," says Elliot, "according to some studies, clothing sheds more in the first few washes and wears than they do over time."

In addition to installing washing machine and dryer filters, Leung suggests that, "consumers can select and wear clothing made of natural fibers which are biodegradable without the long-term harmful impacts of artificial fibers."

"You can also air dry/hang dry most of your clothing so that the dryer won't vent the fibers into the environment," adds Elliot.

COLLABORATING ON SOLUTIONS

"The fiber fragmentation issue is a global challenge that will only be solved through collective action," states TMC. There are many players in the quest to reduce fiber fragment pollution, from fiber chemists to the final consumer, to wastewater treatment engineers, but all need to change behaviors in order to make an impact. From a design standpoint, choosing fabrics that have low fiber fragmentation and, as research progresses, dyes and finishes that don't have adverse affects if the fibers do produce fragments, will be the most crucial.

Academic collaborations are key, says TMC. The organization is actively engaged in studies using a "science-led" approach with the University of Leeds to understand and reduce fiber fragments. Further identifying the most problematic of fiber fragments and filling in knowledge gaps of the impact of fiber fragment pollution is a critical next step. A number of TMC's signatories are involved with Southern California Coastal Water Research Project assessing the potential health impact of fiber fragments to humans.

"Currently, other losses (e.g. in the supply chain) and other pathways (e.g. air) are lacking standardized methodologies," notes TMC.

TMC notes its historical relationship with AATCC through the development of the test method and supporting "round robin" testing. To enable further supply chain collaboration and visibility, TMC has created The Microfibre Data Portal, which currently captures data connecting TMC Test Method results and technical specifications from their signatories. Going forward, they hope to include other test methods results and build out the database with collaboration from testing laboratory partners and industry players. "The inclusion of data from other methods would enable us to scale at a greater pace to get to root cause understanding," and TMC asks, "the AATCC community to give feedback."

Fiber fragmentation testing should become part of the standard specifications conveyed by fabric manufacturers and perhaps even by brands and retailers to the final consumer. As new research studies continue to shed light on the true impacts of the global spread of fiber fragment pollution, the textile industry has an opportunity to make major improvements to its products for the good of the planet and all of its inhabitants.

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