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California Microfiber Update: Textile Perspective

Based on the questions identified by California's environmental agencies mandated to manage microfibers, Materevolve curated the "California Microfiber Workshop: Science, Innovation & Connection" to bring together 85 California leaders in marine science, policy, and sustainable textile innovation to connect, share knowledge, and discuss solutions for microfiber pollution.

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

National Marine Sanctuary Foundation

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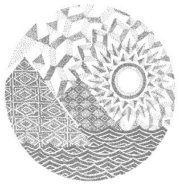

About the Authors

Krystle Moody Wood is the founder and principal consultant of Materevolve, LLC, a technical textile consultancy driven to lead the evolution of our materials world. Materevolve's mission is to develop and scale innovative regenerative textile systems through the lens of soil, sea and circularity by designing nature-forward experiential learning programs, providing technical consulting to leaders in the textile sector, and fostering trail-blazing collaborations between science, industry, government, and non-profit.

With over 13 years of technical textile development experience working for large scale brands (VF, The North Face, Vans, and more), with sustainably minded non-profits (Fibershed, Green Science Policy Institute, 5 Gyres) and with new materials innovators, Krystle brings both a science-led approach and a diverse community to building the future of textiles and sustainable products. Krystle earned her Bachelor's of Science in Textile Science from the University of California at Davis and has been working towards applying her textile knowledge to support the plastic pollution movement for 4 years.

Carolynn Box is an environmental consultant, with 20 years of ocean conservation experience, with the last 10 years dedicated to plastic pollution. Carolynn has traveled more than 25,000 miles researching microplastics on Ocean Expeditions with 5 Gyres. She received a Master's from the University of Rhode Island in Marine Affairs in 2005 and worked in the field of Coastal Management for seven years in the San Francisco Bay.

After her first 5 Gyres Voyage in 2011, a 33-day trip across the South Atlantic Gyre, she decided to change the course of her life and apply her science and organizing background to efforts to fight plastic pollution. Carolynn has participated on 10 Ocean Expeditions, with the Expedition Leader role on many of them. Carolynn was happy to bring her passion and experience to her backyard where she lead up the policy process that was built into the San Francisco Bay Microplastics Project, along with being part of project development, design, fieldwork, and analysis. Carolynn is currently working on a number of projects that are focused on microfiber pollution and solutions in California.

Carolynn also addresses the issue of plastic pollution through her small plastic free lifestyle company, Goods Holding Company, that she co-founded in 2017. In 2020, Carolynn and colleagues in the Bay Area established the California Reuse Collective, a network of companies focused on building reuse systems in the Bay Area. www.carolynnbox.com

1. California Microfiber Workshop

California-based sustainable textiles consultancy Materevolve and the National Oceanic and Atmospheric Administration (NOAA) Marine Debris Program partnered to host an engaging workshop entitled **"California Microfiber Workshop: Science, Innovation & Connection,"** on November 17, 2020. Support for this workshop and report was provided by a grant from the National Marine Sanctuary Foundation. The workshop was curated and organized by Krystle Moody Wood (Founder & Principal Consultant at Materevolve) and Carolynn Box (Ocean Conservation Consultant, formerly with 5 Gyres). It was an invitation-only workshop, centered around the complexities of microfiber pollution and textile solutions.

a. How was the workshop designed?

Representatives from the NOAA Marine Debris Program, the California Ocean Protection Council (OPC), and California State Water Resources Control Board (California State Water Board) were involved in the design of the California Microfiber Workshop.

The following questions were identified during planning meetings working up to the California Microfiber Workshop:

- What key resources or solutions to microfiber pollution are we missing? How can the plastic pollution movement support textile professionals?
- How can we break down knowledge and language barriers between sectors and consumers? What kind of messaging is important?
- What can policymakers, businesses, and citizens do today? What are the priorities in research, connection, and innovation?

The California Microfiber Workshop aimed to answer these questions, bring together new stakeholders from the textile industry, and build momentum towards microfiber pollution solutions.

The workshop brought together **85 California leaders** in marine science, policy, and sustainable textile innovation. A full list of speakers and participating companies/organizations are included at the end of this report.

The workshop was broken into two parts:

1. **State of the Issue**: Three sessions of concise presentations from 13 strategically selected experts provided an overview of the issue of microfiber pollution from different perspectives.

2. **Discussion and Connection**: Facilitated breakout sessions focused on getting direct feedback from the invited stakeholders to understand on-going research and efforts.

b. How was this report generated?

This report summarizes the issues and ideas presented by the speakers and participants at the California Microfiber Workshop. The solutions presented cover a range of techniques and ideas that were discussed during the workshop. The themes and questions that were asked by multiple stakeholders have been described.

2. Overview of the Issue

Microfibers have been found to be the dominant form of microplastics in drinking water, soils, and in most aquatic ecosystems. Increasing global and regional studies suggest that microfibers can be found at high levels throughout the environment. The research landscape microfibers has greatly increased in the last decade (see Figure 1 on the right).

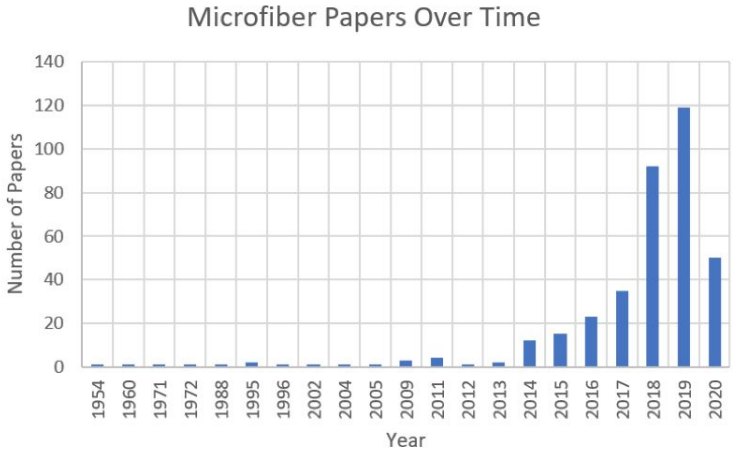

Figure 1. Microfiber Papers Over Time (Royer, 2020)

With the increase in microfiber pollution awareness and interest, many research efforts are now looking to evaluate and develop solutions to reduce microfiber inputs, with much of the focus upstream. Multiple efforts have been initiated to measure, develop, and better understand what solutions are needed to move forward.

Through new proposed and adopted legislation in California, key government agencies have been tasked to address microfiber pollution. This workshop brought together many key experts in science and innovation, across multiple sectors, with this goal in mind.

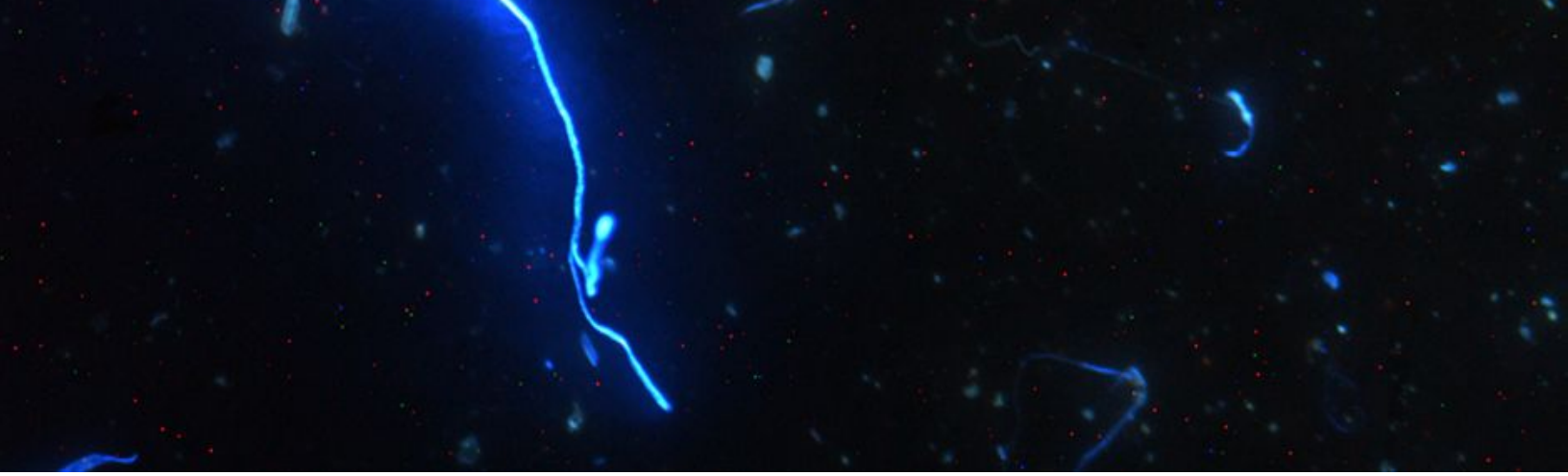

Photo Credit: Sarah-Jeanne Royer

a. What is the definition of microfiber?

To build a shared understanding, it is important to be aware that definitions of the term "microfiber" differ between key communities looking for solutions.

OCEAN SCIENCE DEFINITION

To the ocean science community, the term "microfiber" refers to particles that are characterized by their thin and fibrous shape and are found in the environment (i.e., water, air, soil, etc.). Microfibers are a shape category of microplastics (a plastic particle that is less than 5mm in any one direction).

Recently, the focus for most microfiber pollution research and communication is on anthropogenic plastic fibers, such as polyester, polyamide (nylon), acrylic, polyurethane, polypropylene, and polyethylene. At the same time, in an effort to characterize the type of material found in each environment, research lab equipment is picking up chemical signatures from added chemistry such as dyes and finishes.

The definition is based on current scientific reports (Sutton et al., 2019, Gavigan et al., 2020) but differs slightly from the recent adopted "microplastics" definition by the California State Water Board (see page 14 for more information).

TEXTILE SCIENCE DEFINITION

The textile community has been using the term "microfiber" publicly for over three decades. To the textile community, a microfiber is a very fine synthetic, or human made, fiber. Technically, a microfiber is a human made fiber defined by less than or equal to 1 Denier. Denier is a textile unit that equals the linear mass density of fibers or the mass in grams per 9000 meters of fiber.

Microfibers have been utilized widely for many decades to achieve new material characteristics to alter textile physical appearance, processing efficiency (i.e., improves dyeability, reduces dry time, etc.), moisture management properties (i.e., quicker drying, improves moisture spread for better wearer comfort, etc.) and more. A microfiber can be derived from a wide range of material types including plastic, cellulose, and protein. Many leaders in the textile industry related to this topic are using the term "fiber fragmentation" or "fiber fragment" instead of "microfiber." Learn more about these organizations later in the report.

b. Why is microfiber pollution important?

Recent studies focusing on California indicate that microplastics, specifically microfibers, are ubiquitous in our natural environment (Sutton et al., 2019; The Nature Conservancy, 2020). The San Francisco Bay Microplastics Project suggests that stormwater systems, made up of rivers, streams, and all of the storm drains that empty into them, contribute more than seven trillion microplastics each year, with 39% of the particles being microfibers. Quality control samples collected as part of the same study that should have included no microplastics at all were found to include microfibers, suggesting air may be an important pathway for microfibers to enter the environment.

Another study conducted by The Nature Conservancy and the University of California Santa Barbara Bren School of Environmental Science and Management (Bren) in fall 2020 found that in 2019, an estimated 4,000 metric tons (or 13.3 quadrillion fibers) were released into California's natural environment (The Nature Conservancy, 2020). Together these studies suggest that microfibers could be an important pollutant. The two studies aim to understand microfiber pathways and sources, though both pathways and sources are complex and not fully understood. Figure 2 generally describes pathways and sources of microfibers for the San Francisco Bay and beyond (Sutton et al., 2019).

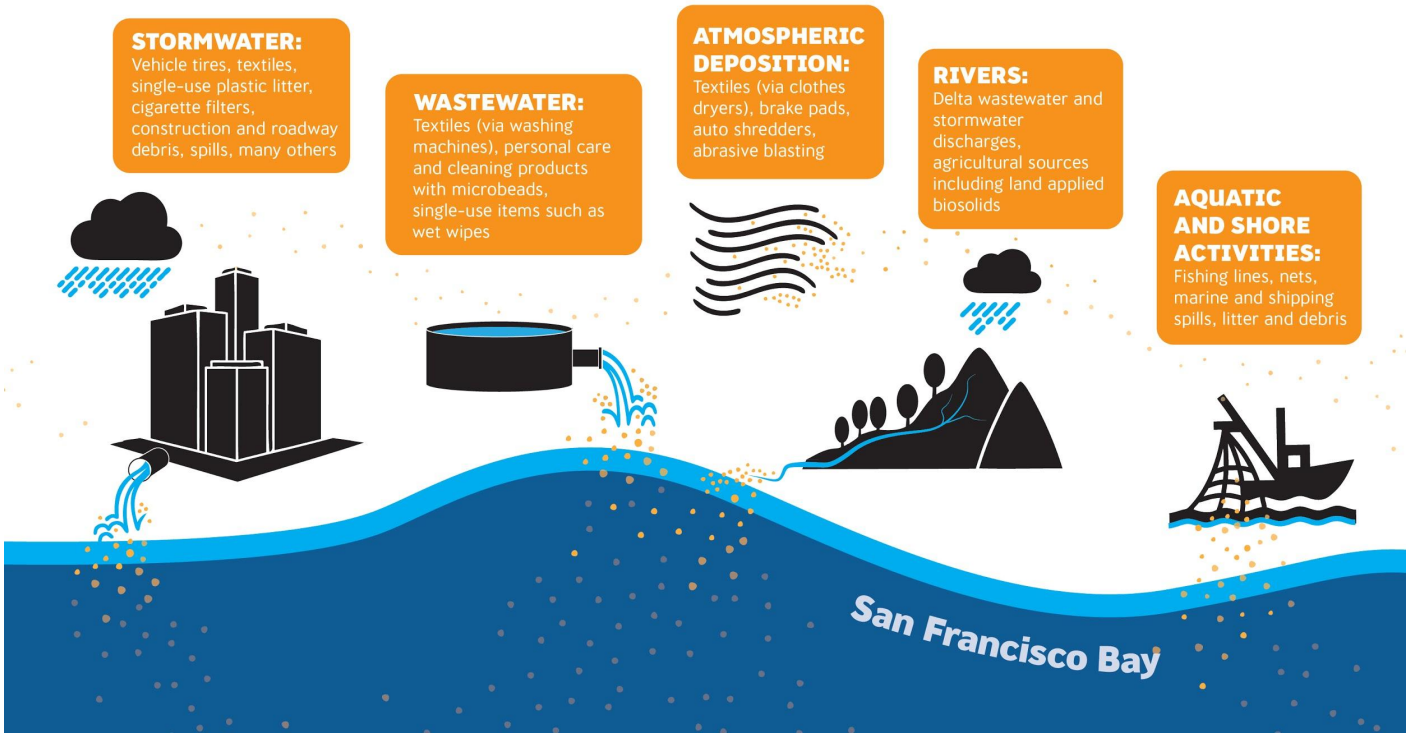

Figure 2. Potential microfiber sources and pathways identified as part of the San Francisco Bay Microplastics Project (Sutton et al., 2019)

Like many microplastics, microfibers can contain harmful chemical additives, such as flame retardants, stain/water repellents (i.e., per- and polyfluoroalkyl substances), and more. Once in the natural environment, they may absorb other harmful chemicals and, when ingested, the chemicals can be biomagnified up the food chain (Rochman et al., 2014). Hazards are not well known for microfibers (physical toxicity seems to be the dominant driver with sorbed contaminants less certain), but it is reasonable to expect these materials to cause toxicity at similar levels to other microplastic shapes. Hazard thresholds for microfibers are not yet available, thus estimation of risk is not yet possible. With increasing data available at both the aquatic and terrestrial level, it is still unclear what this actually means for ecosystems and humans (Jaques et al., 2020). Regardless, according to the San Francisco Bay Regional Monitoring Program, the persistent nature of microfibers necessitates concern (San Francisco Estuary Institute, 2019).

c. What are microfiber emissions globally?

A recent study estimated that 5.6 million metric tons of synthetic microfibers were emitted globally from apparel washing between 1950 and 2016 (Gavigan et al., 2020). Half of this amount was emitted during the last decade and about 2.9 million metric tons of the microfibers ended up in water bodies around the world.

Another important finding in this global microfiber emission model was that a significant portion of fiber effluent is captured at the wastewater treatment stage and re-introduced back into the environment through the use of biosolids as land amendments. Questions related to the management of sludge from wastewater treatment plants came up during the workshop as sources and solutions were discussed.

Globally, it is estimated that approximately eight million metric tons of plastic pollution entered our ocean from land in 2010, and more than approximately 250,000 tons of plastic particles are floating on our ocean's surface (Jambeck et al., 2015; Eriksen et al., 2014). More and more studies are looking specifically at microfibers, not only in our ocean but in inland environments as well. A study done through a network of citizen scientists found that on average samples collected in our ocean and from rivers around the world had an average of 11.8 ± 24.0 particles per liter of water (Barrows et al., 2018).

d. What are microfiber emissions in California?

Preliminary results from a study done by Bren and The Nature Conservancy estimate that up to 4,000 metric tons of synthetic microfibers may enter California's natural systems each year.

Regionally, the San Francisco Bay Microplastics Project, a study done by the San Francisco Estuary Institute (SFEI) and 5 Gyres, looked at pathways and sources of microplastics (including microfibers) in the San Francisco Bay. The project estimated that stormwater (0.5-10 fibers per liter) and wastewater (0.006-0.1 fibers per liter) both release microfibers into the San Francisco Bay (Sutton et al., 2019). The project also identified science-supported recommendations, with better understanding the effectiveness of filtration as one of the key recommendations (Box & Cummins, 2019).

Studies in the Lake Tahoe region, done by the Desert Research Institute and the University of California at Davis, Tahoe Environmental Research Center, will quantify microplastics (including microfibers) in surface waters and rivers in the region. The Desert Research Institute is also assessing dryer vents as a source of microplastics to the environment, and looking at mechanisms to reduce dryer vent emissions (Kapp & Miller, 2020; O'Brian et al., 2020).

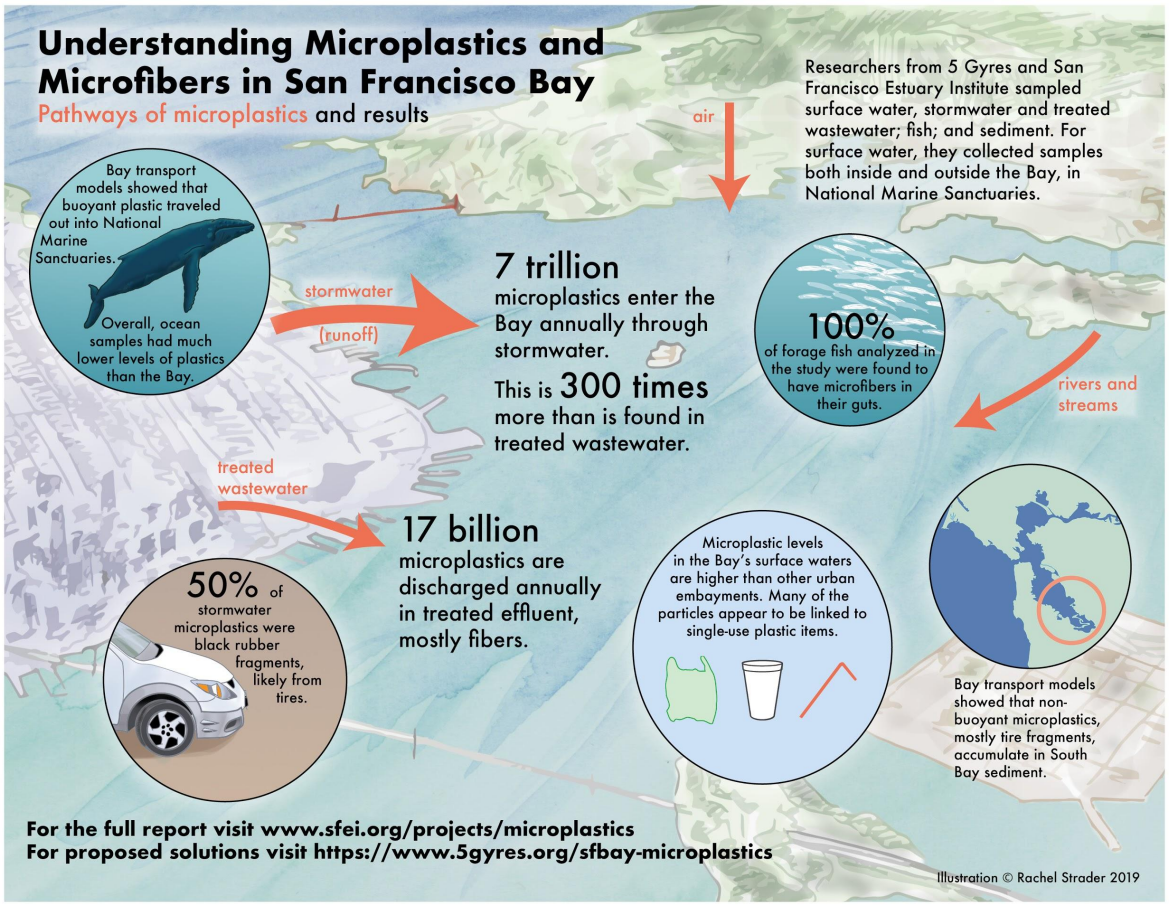

Figure 3. Microplastics and microfibers in the San Francisco Bay (Image by Rachel Strader)

e. Who are the key stakeholders addressing microfiber pollution?

TEXTILE INDUSTRY STAKEHOLDERS

Acknowledging that microfibers can come from a variety of different textile sources across many sectors, the California Microfiber Workshop brought in sustainable textile brand leaders from apparel, footwear, equipment, bedding, carpet, laundry, and uniform rental services. Sustainable brands play an important role in influencing product design, producer engagement, and consumer education. The apparel sector was the most represented in the workshop.

In addition to brand leaders, it is important to also bring in textile manufacturers and processors, textile chemistry experts, dye and finish manufacturers, fiber manufacturers, and materials innovation companies (in both synthetic and natural) to represent each tier for the product supply chain. With Los Angeles as a large manufacturing hub for knitting, dyeing, and finishing, California has the opportunity to bring in engagement across the textile value system.

Increasing studies and media attention on fiber release from laundering show that organizations such as the Association of Home Appliance Manufacturers (AHAM), potential solution providers in filtration (i.e., Wexco, Filtrol), and innovative laundry technology companies (i.e., Tersus Solutions) have an important role to play in research and solutions.

GOVERNMENT STAKEHOLDERS

Many local, statewide, and federal agencies play an important role in the management of microfiber pollution. Agencies that are responsible for managing coastal development and pollution, water quality (drinking water and natural environment), wastewater and stormwater, trash and recycling, and environmental education all have a responsibility (and often are mandated) to monitor, control, and build awareness on microfiber pollution. Other agencies responsible for conservation of marine protected areas, marine wildlife, birds, land preservation, and others, may also be important to involve depending on the projects.

Additionally, local entities, such as a city's environmental department, may implement new regulations related to microfiber pollution. For example, the University of Toronto is currently conducting a regional study that is evaluating the effectiveness of microfiber filtration options in a small community. This project required local governmental involvement, along with coordination with many of the regional municipalities. Through the San Francisco Bay Microplastics Project, SFEI has monitored effluent for microplastics and microfibers at a number of Bay Area

Some government agencies are focusing on microplastics and microfibers research, such as the United States Geologic Survey and NOAA, and may also be important stakeholders to coordinate research efforts.

OCEAN SCIENTISTS

Ocean scientists play an important role in helping industry and legislators to quantify microfibers in the natural environment, while also identifying pathways and sources of microfiber pollution. Many ocean scientists are affiliated with universities or research institutes. There are also a number of non-profits that carry out work related to microfiber pollution, including citizen science and beyond. Some of the leading entities in California are summarized in Figure 5 on page 15.

ACTIVISTS AND NON-PROFITS

Activists and non-profits support research, education, and communication, while helping to prioritize and suggest potential solutions for microfiber pollution outside of government and textile brand efforts.

Some of the leading California non-profits that are focused on microfiber pollution are: Break Free From Plastic, Peak Plastic Foundation, 5 Gyres, Californians Against Waste, Moore Institute for Plastic Pollution Research, along with several others. Not all of these organizations were represented at the workshop.

3. Current Efforts: Microfiber Policy, Management, and Research in California

California organizations continue to lead the plastic pollution movement with their efforts to address microfiber pollution through statewide strategies, research, and proposed legislation. Other states and countries look to California for guidance on managing plastic pollution and the same is true for microfiber pollution.

a. What is California doing to manage microplastics and microfibers today?

California's statewide plastic pollution reduction efforts started in the early 1970s when the Water Quality Control Plan for Ocean Waters of California (Ocean Plan) established the California State Water Board. The California Coastal Commission began annual statewide beach cleanup efforts in 1985 that now draw over 70,000 people to the beach each September. Alongside these efforts, in the 1980s and 1990s, several cities implemented ordinances to ban the use of expanded polystyrene takeout containers and plastic bags.

Efforts to further address plastic pollution around the state began in 2004 when the OPC was formed by the California Ocean Protection Act. The new statewide agency was set up to coordinate governance and stewardship of the state's ocean, identify priorities, bridge existing gaps, and ensure effective and scientifically sound approaches to protecting and conserving the most important ocean resources. In 2016, the OPC and the NOAA Marine Debris Program began work on what would ultimately become the 2018 Ocean California Litter Prevention Strategy (Litter Strategy). The Litter Strategy is a statewide plan that addresses plastic pollution from source to sea, including goals that address microplastics, with specific goals on microfibers. Microplastics and microfibers are identified as priority items to address. Most recently, the California legislature mandated the OPC to work with scientific experts to develop a California Microplastics Strategy (SB 1263), which will lay out specific goals to reduce microplastics, including microfibers.

The California State Water Board identified trash (all litter larger than 5mm) as a contaminant and implemented "Trash Amendments" to the Water Quality Control Plan for Ocean Waters of California (Ocean Plan) and Part 1 Trash Provision of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries (ISWEBE Plan) that were put in place in 2015. This mandated cities and counties to develop plans to monitor and reduce trash entering the natural environment. The California State Water Board began to address microplastics through the Pre-Production Plastic Debris Program in 2007, which set up enforcement options for pre-production pellet (nurdle) pollution.

The California State Water Board is also responsible for setting drinking water standards and has recently been mandated to develop methods to quantify microfibers in California's drinking water, along with set thresholds based on best available science (see page 13 for more detail).

The California State University Council on Ocean Affairs, Science and Technology (COAST) recently provided microplastics and microfiber research grant funding to Dr. Eunha Hoh and Dr. Chelsea Rochman for microplastics to assess toxicities of leachates from microfibers to zebrafish.

b. What recent statewide strategies are in place related to microfibers?

The NOAA Marine Debris Program and Ocean Protection Council support microfiber pollution solutions through the **California Ocean Litter Prevention Strategy.** It includes the following actions that require research and messaging about microfibers:

- Action 4.2.2. Research innovative solutions to address microfibers in textiles and apparel.
- Action 4.2.3. Research technological solutions to address microfibers at wastewater treatment plants or in washing machines.
- Action 5.2.2. Develop messaging for consumers and producers on microfibers given our current state of knowledge on this emerging issue.

Ocean Protection Council was charged through state legislation (SB 1263) to develop a Statewide **Microplastics Strategy for California** that will be completed by December 2021.

The strategy aims to assess ecological risks, investigate sources and pathways, and evaluate solutions and recommend policy.

The OPC has created a science advisory team to develop a risk ranking framework for microplastics that will be created in early 2021.

The OPC, the California State Water Board, Southern California Coastal Water Research Project (SCCWRP), and University of Toronto organized a microplastics health effects panel that will determine a risk-based threshold for microplastics (including microfibers) for aquatic environments and human health.

California Senate Bill 1422 mandated the California State Water Board to define microplastics and develop standardized methods to quantify microplastics in drinking water. On June 6, 2020, the following definition for microplastics was adopted by the California State Water Board:

> *"solid polymeric materials to which chemical additives or other substances may have been added, which are particles which have at least three dimensions that are greater than 1 nanometer and less than 5,000 micrometers. Polymers that are derived in nature that have not been chemically modified (other than by hydrolysis) are excluded. (Microfibers have been defined as a microplastic with a 'length to diameter ratio of >3')"*

The California State Water Board hosted a series of webinars exploring the health effects of microplastics in Fall 2020. For method development, the California State Water Board is working with Southern California Coastal Water Research Project (SCCWRP) and more than 35 laboratories around the world to develop standardized methods on how to quantify and identify microplastics, including microfibers.

Official Adopted Definition (June 6, 2020) 'Microplastics in Drinking Water'

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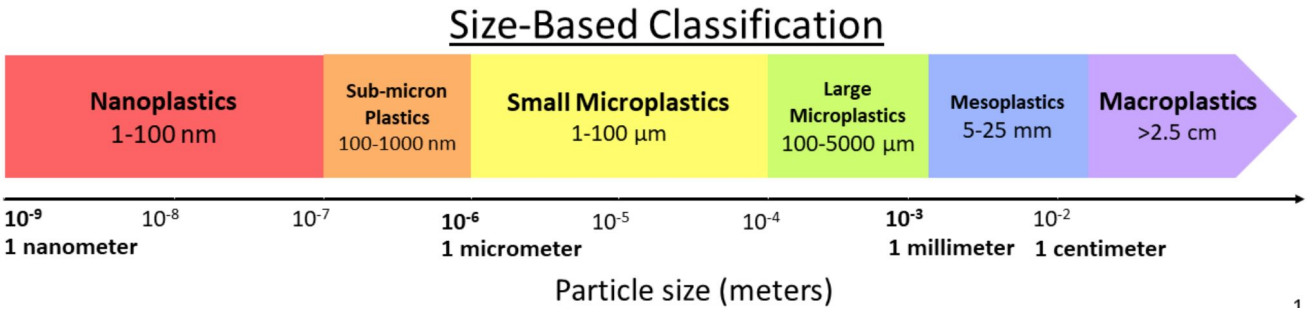


Figure 4. Microplastics definition by the California State Water Board (Coffin, 2020)

c. Does the new California 'Microplastics in Drinking Water' definition include natural fibers, such as cotton and wool?

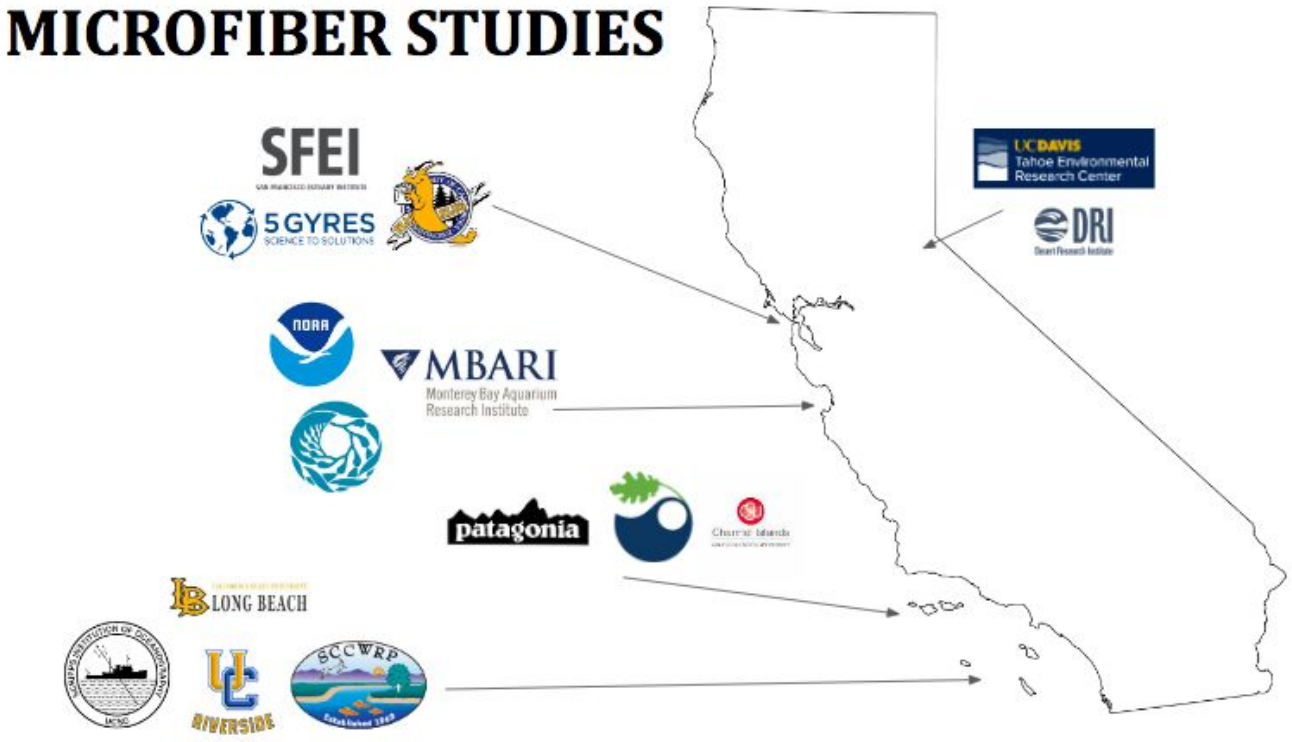
Currently, almost all of textile production today, across all sectors, utilizes synthetic dyes and finishes. This means that all natural fiber materials such as cotton, wool, linen, hemp, silk, etc., have been chemically modified to impart color, add performance features, or improve textile properties. According to the California State Water Board, 'synthetic fibers' are included as a non-traditional plastic considered within the definition of 'Microplastics in Drinking Water' adopted in June 2020 but it is unclear at this time if this definition would also include natural fibers. Under this definition, it is possible that dyed and finished natural fibers may be considered "microplastics" if they are less than 1% synthetic polymer by mass, or if the particle is completely encompassed in synthetic polymer.

Leading up to the workshop, Materevolve and California State Water Board representative Scott Coffin, engaged with textile chemists and processing experts to understand if natural fibers could also be included in this definition. This inquiry led to the identification of a significant knowledge gap and lack of shared understanding between the ocean science community, government agencies, and the textile industry on the potential impacts of textile chemistry on nature-derived materials. This topic was explored in the workshop but further research and cross-sector collaboration is needed to better answer this question and/or define if natural fibers should be included as a 'microplastic'.

d. What microfiber research is happening in California?

More than 15 entities around the state have active projects on microfibers aimed to understand pathways and sources. This list includes entities and researchers that the workshop organizers were able to connect with and may not be an exhaustive list for the entire state.

California Microfiber Research Groups To Follow



San Francisco Estuary Institute: https://www.sfei.org/projects/microplastics
5 Gyres: https://www.5gyres.org/sfbay-microplastics
University of California, Santa Cruz: https://campusdirectory.ucsc.edu/cd_detail?uid=klbowman
Desert Research Institute: https://www.dri.edu/labs/microplastics/
University of California, Davis Tahoe Environmental Research Center: https://tahoe.ucdavis.edu/
Monterey Bay Aquarium Research Institute: https://www.mbari.org/
The Nature Conservancy: https://www.nature.org/en-us/newsroom/california-microplastics/#
NOAA, Monterey Bay National Marine Sanctuary: https://montereybay.noaa.gov/vc/sec/
Patagonia: https://www.patagonia.com/stories/what-were-doing-about-our-plastic-problem/story-72799.html
University of California, Santa Barbara Bren School of Environmental Management: https://bren.ucsb.edu/research
SCCWRP: https://www.sccwrp.org/about/research-areas/regional-monitoring/
University of California, Riverside: https://andrewgray.ucr.edu/
Scripps: https://choylab.ucsd.edu/ and https://deheynlab.ucsd.edu/research/microfibers/
California State University, Channel Islands: http://clarewormaldsteele.cikeys.com/microplastics/
California State University, Long Beach Tox Lab: https://www.holland-toxlab.com/cv
Moore Institute of Plastic Pollution Research: https://mooreplasticresearch.org/

Figure 5. California research groups that are working to research microfibers (Box, 2020)

e. What role does biodegradability research play in microfiber pollution and textile solutions?

Persistence is a principle trait of concern for microplastics and is inspiring a general push for understanding and designing with biodegradability in mind. As more microfiber pollution research data is available, it is clear that synthetic fibers aren't the only fibers present in our environment in significant volumes (Suaria et al., 2020). With the bulk of current global fiber demand committed in synthetic materials (polyester is in highest global demand), many textile companies are looking to transition to "biodegradable" materials both in traditional natural fibers systems (i.e., cotton, wool, linen, hemp, etc.) and in human made synthetic fiber systems (i.e., cellulosics, polyester, nylon).

Dr. Sarah-Jeanne Royer of Scripps Institute recently conducted a study that evaluated a range of different microfibers, natural and synthetic, over 231 days, documenting degradation in a marine environment. The preliminary results suggest that the natural materials in the study (cellulose-based and cotton-based) fully degraded, while blended, bio-based polymers and synthetic microfibers degraded much less (Royer, 2020). The full details of this research will be published in 2021.

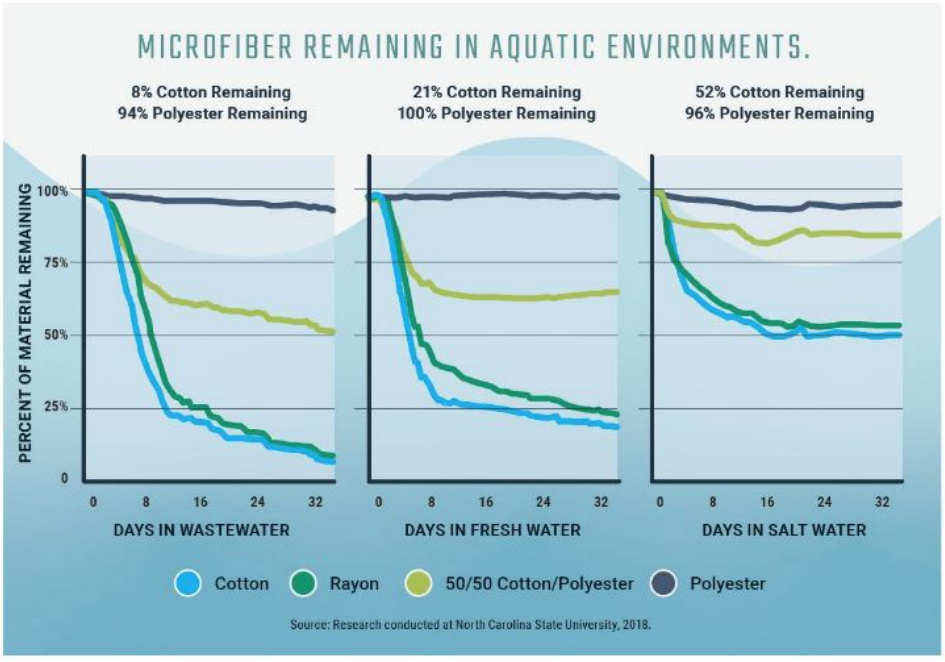


Figure 6. Microfiber Remaining in Aquatic Environments (Cotton Incorporated, 2018)

United States-based Cotton Incorporated and the Cotton Research and Development Corporation in Australia commissioned North Carolina State University to look at how cotton biodegrades in various aquatic environments. The research objective looked at the degradability of various types of microfibers, both cotton and synthetic, along the path from laundry wash to waterways. After 243 days, cotton yarns had degraded 76% by mass while polyester had only degraded by 4% (Zambrano et al., 2019). Follow up research, with refined methodology (test standards ISO14851:1999, 2005 and ASTM D6691), looked at cotton, rayon, polyester, and cotton/polyester fabrics in multiple aquatic environments: wastewater, freshwater, and saltwater (see Figure 6 above) and found that cotton and rayon degrade more readily than polyester. (Zambrano et al., 2020). Cotton Incorporated is also studying the impact of dyes and finishes on degradability.

While some test method standards for biodegradability and compostability in plastics do exist, these test methods represent a very narrow set of parameters set to mimic specific environmental conditions (i.e., landfill, marine environment, etc.), but are conducted in a lab. Additionally, while the base materials may be subject to biological processing in these studies, it is unclear how synthetic dyes and finishes change the ability of the material to biologically decompose or whether the residuals are toxic or non-toxic to the environment. With that said, more research and discussion are needed across sectors to understand the role of biodegradation.

4. Solutions: Consumer and Industry

Consumer and industry solutions to microfiber pollution can range from filtration to techniques to reduce shedding in textile manufacturing and fabrication of apparel. Building awareness through both public education campaigns and stakeholder groups can also be powerful.

a. How effective are consumer solutions and filtration at the laundering stage?

Initial focus for mitigating microfiber pollution worldwide has included a heavy emphasis on the laundering stage of the apparel and textile lifecycle, particularly during washing. With a lack of filtration on current washing machines, there have been multiple first-to-market products offered to global consumers to take on the role of mitigation in their own personal laundry routine. California companies Patagonia, Reformation, and Toad&Co have sold their products with a washing bag (i.e., Guppyfriend Washing Bag) developed to capture fiber fragments during each load and reduce agitation in the wash load. The Cora Ball, a plastic device that can be thrown into your washer to capture fiber fragments, has also been offered to consumers as a way to mitigate their microfiber footprint. Companies, such as Filtrol and Lint LUV-R, are offering in-line filtration devices that you can install in your home to mitigate the release of textile fiber from washing machines into municipal water systems. Results from research conducted at the University of Toronto was presented at the workshop showing that the Cora Ball captured 26% of the microfibers (by weight), Lint LUV-R captured 87% of the microfibers (by weight), and Fitrol captured 89% of the microfibers (by weight) (McIlwraith et al., 2019). It is important to note that capture efficiency can vary with fiber type (i.e., polyester versus nylon) and lint filter pore size as seen in an upcoming study by Ocean Wise (Vassilenko et al., 2021). Textile fibers have a greater chance of passing the traps equipped with a large pore internal filter. Details of this research will be available in Spring 2021.

Another mitigation solution being explored by California legislators and the ocean science community to disrupt the flow of fibers to our waterways by mandating filtration installation on home and industry laundry equipment (AB 3232 was introduced in February 2020). The University of Toronto (UoT) also presented on a community-level research study currently taking place in the town of Parry Sound, Ontario, Canada. In this study, UoT helped research participants install 100

filters in July 2019, about 10% of the homes connected to the municipal wastewater treatment plant, and evaluated the fiber fragment capture before and after installation. Initial results show that this solution is effective at mitigating fiber effluent, even at 10% implementation for this community.

b. What solutions can individuals take now?

Studies have been carried out in California and beyond to understand what individuals can do today to reduce microfibers from entering the natural environment. Many of the suggestions focus on washing apparel in home washing machines, with specific suggestions to reduce microfibers. Figure 7 provides a list of simple tips that individuals can take now to reduce their microfiber impacts supported by Ocean Wise and other research entities (Ocean Wise, 2020; Hartline et al., 2016, Sutton et al., 2019).

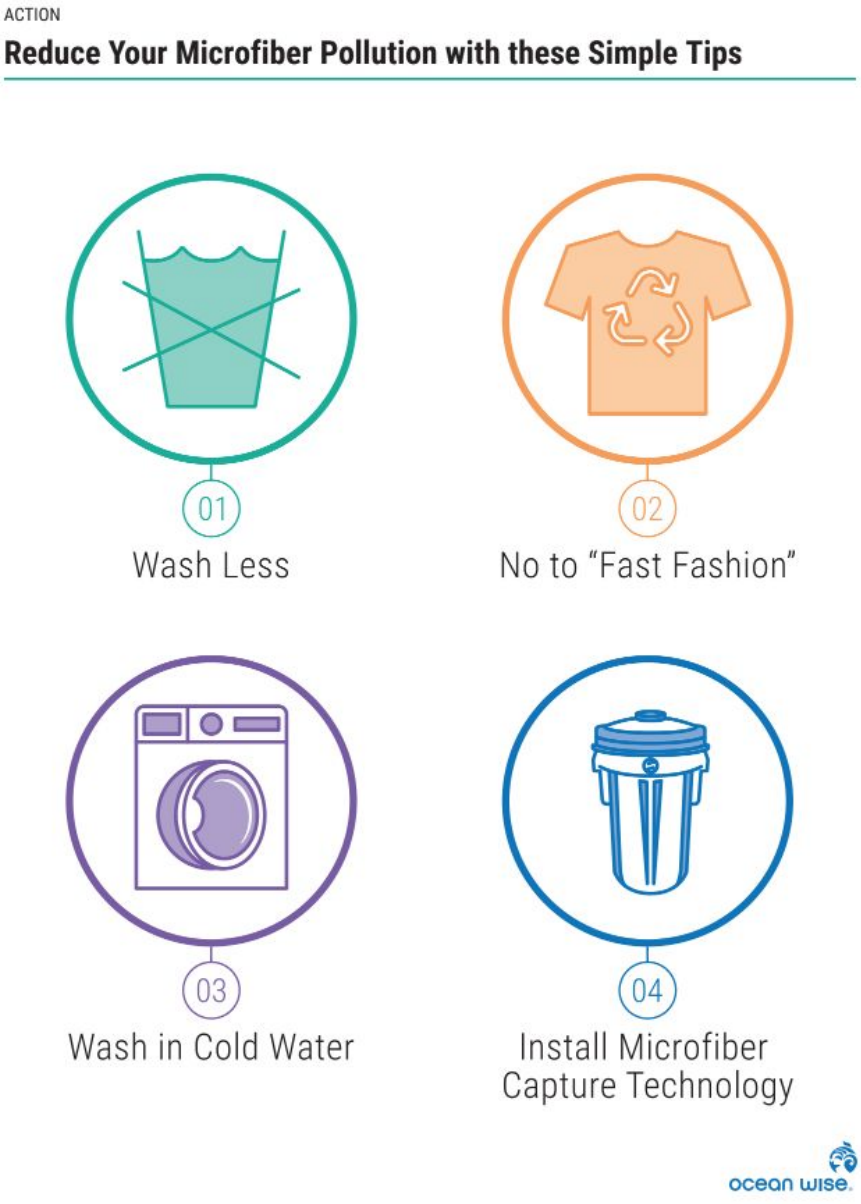


Figure 7. Reduce your microfiber pollution with these simple tips (Vassilenko et al., 2019)

c. How is the textile industry addressing microfiber pollution today?

This section highlights solutions presented, discussed, or represented at the workshop and doesn't necessarily endorse their products or services. This section is also not a comprehensive representation of all solutions in development or in the market today.

INVESTING IN RESEARCH

Since 2016, Patagonia, a California company, has been leading both producers and consumers to understand the issue of microfibers and how it is related to the apparel industry. Their research focuses on understanding the shedding rates of different materials during washing and the pathways of microfibers entering the natural environment, and has recently shifted to understanding the impact of dyes and finishes on biodegradability. In the last four years, many other apparel and footwear brands have joined in this effort to support research, quantify impacts, and develop the measurement methods needed to implement and evaluate solutions. The carpet, bedding, and white goods sectors are still new to this issue and were interested to understand how the apparel and footwear industry are advancing knowledge and research for this issue.

EDUCATING ON CONSUMER CARE

With a large amount of fibers released in laundering, many textile brands have taken steps to educate their customers on steps to reduce microfiber shedding, including washing products less often and the tips included in Figure 7.

DEVELOPING GLOBAL FIBER RELEASE TEST METHOD

To be able to assess potential solutions effectively, the textile industry is eager to align on a global test method to measure fiber release. Leading this effort in the United States is the American Association of Textile Chemists and Colorists (AATCC). AATCC is a not-for-profit trade organization that includes employees of textile, apparel, and home goods manufacturers, dye and chemical manufactures, testing laboratories, consumer and retail organizations, and others. AATCC is internationally recognized for its standard methods of testing fibers and fabrics to measure and evaluate performance characteristics, such as colorfastness, appearance, soil release, dimensional change, and water resistance. Currently, AATCC is finalizing the development of the Fiber Release Global Standardization test method that allows companies to measure fiber release and design products to minimize fiber fragment shedding. This method will support efforts in fabric innovation to minimize or solve the fiber release issues by providing a globally recognized way to evaluate shedding rates.

SHIFTING TEXTILE AND PRODUCT DESIGN

With early testing methodology and an interest in solving this issue, some textile brands have already started shifting their product offering and textile strategy today. In some cases, brands are re-investing in natural fiber systems and moving away from synthetic fibers. In the workshop, Patagonia outlined three microfiber shedding reduction strategies through product design: 1) adding a garment wash in advance of sale to the customer; 2) deploying current technology to dye the yarn at the yarn spinning stage, or solution dyeing, to avoid additional processing typically needed during the fabric dyeing stage; and 3) sourcing quality fabric from quality mill partners to minimize shedding. All of these steps are existing technology or processes that textile brands can take today to minimize excess processing of textiles that causes pre-consumer microfiber release.

The northern California based non-profit Fibershed outlined a new product design framework integrating nature within the product lifecycle. Fibershed supports carbon farming and the development of regional and regenerative fiber systems utilizing materials and dyes found in nature.

INVESTING IN MATERIALS INNOVATION

Textile brands are also looking at how to better quantify and qualify new material technologies that could address microfiber pollution through yarn or textile construction or base material type. Circular Systems, a materials innovation company based out of Los Angeles, is addressing fiber fragment pollution through a patent-pending yarn construction called Orbital Hybrid Yarn. Without a global testing standard in place, Circular Systems has partnered with Germany's Hohenstein Institute to confirm their unique yarn construction's efficacy by running a quantitative analysis on a range of textile constructions. New material innovators, such as California's CiClo or Mango Materials offer synthetic polymers that have been designed with attention to degradability in certain environments (i.e., landfill, marine, etc.). Textile brands and manufacturers are eager to assess and implement innovations that can solve this issue.

COLLABORATING TOGETHER

Across the globe, many textile brands and manufacturers are interested in solving the microfiber pollution issue. Understanding that no one brand can solve fiber release on their own, strategic partnerships and coalitions have been formed to leverage resources, build a shared understanding, and align on steps the industry can take to measure, quantify, and design products differently.

In 2017, the Ocean Wise Plastics Lab launched the Microfiber Partnership with apparel companies MEC, Patagonia, REI, and Arc'teryx, and Canadian government agencies Metro Vancouver and Environment and Climate Change Canada. Phase one research studied a range of textiles to better understand production factors that may impact fiber release. The study showed that the tested textiles had a wide range of fiber shedding rates, from a loss of 9.6 mg to 1,240 mg, or an estimated 9,777 to 4,315,371 microfibers per kg (Vassilenko et al., 2019).

United Kingdom-based non-profit The Microfibre Consortium (TMC) spun out of the European Outdoor Industry Association and now executes within a combined group of brands and manufacturers from outdoor, home, fashion, and sportswear. California brand Patagonia is one of 40+ members, including Adidas, The North Face, Nike, Lululemon, and more, collaboratively engaged to build integrity and aligned testing methodology, share data to support product development change, and institute proactive textile engineering, as well as engage and support suppliers in their management of fiber fragmentation and release. TMC offers a great number of resources on their website. California currently does not have a coalition of brands working together on this issue.

5. Next Steps and Recommendations

During breakout sessions at the workshop, participants were broken into seven groups to better engage with each other and discuss the questions that guided the workshop (see page 4). The questions and themes were not formally prioritized during the workshop, however, many of the breakout groups had similar discussions and themes that are summarized below. The following subsections represent the opinions expressed by workshop participants, and not necessarily the authors or funders of this report.

a. What key resources or solutions to microfiber pollution are we missing?

RESEARCH

- Evaluating human health and significant biota impacts
- Assessing impacts of textile chemistry and textile construction on fiber release and biodegradability
- Studying viability of industrial and home laundry filtration
- Understanding transport pathways through atmospheric deposition

CONNECTION

- Continuing to work collaboratively on building a shared understanding, methods of measurement, and prioritization of solutions
- Building both natural fiber and synthetic fiber systems into materials research and solutions
- Working across sectors to define biodegradability, compostability, and thresholds for healthy living systems

INNOVATION

- Re-thinking textiles systems holistically and with circularity in mind
- Re-investing in natural fiber systems
- Designing synthetic inputs with smaller molecules for biodegradability and with renewable feedstocks

b. How can the plastic pollution movement support textile professionals?

To date, the plastic pollution movement has not had deep involvement by textile stakeholders to discuss solutions to plastic pollution or microfiber pollution (as compared with stakeholders from the single use plastic industry). With multiple statewide agency efforts to manage and reduce plastic pollution in California, and microfibers now listed as a priority, there is an opportunity to bring in new perspectives and expertise from the textile professional community. There are upcoming public comment periods, working groups, and stakeholder meetings where it would be strategic for textile professionals to be invited to engage in policy efforts.

Textile professionals can stay engaged by signing up for updates about the California Ocean Litter Prevention Strategy and California Microplastics Strategy at their website.

To stay engaged with microfiber pollution at the California State Water Board:

1. Follow #TrashDataDive on Twitter
2. Join the Trash Monitoring Workgroup

c. How can we break down knowledge and language barriers?

- Translating results and solutions in simple language so non-scientists within the textile industry can understand
- Inviting a range of stakeholders (including textile professionals, white goods industry professionals, carpet industry professionals, tire manufacturing, and other potential professionals that work with microfiber sources) to participate in all planning stages and

- Defining terms (i.e. microfiber, microplastic, biodegradability, etc.) with cross-sector leaders on this issue to achieve a shared understanding
- Building an overarching coalition or cross-sector effort to coordinate collaboration and communication of shared definitions, research, and solutions
- Hosting additional forums and meetings that encourage collaboration between stakeholders to continue to identify and prioritize solutions

d. What kind of messaging is important for producers and consumers?

- Avoiding using terms related to textiles, such as compostability and biodegradability, until definitions, testing, environmental conditions, and thresholds have been agreed upon
- Recognizing that not all natural fibers are good and synthetic fibers are bad and addressing the complexity with producers
- Encouraging extended producer responsibility
- Developing messages for consumers that are simple and focus on the big picture (e.g., reduce, reuse, and repair)
- Creating graphics to help explain complex issues to both producers and consumers
- Encouraging communication between stakeholders and the general public to provide current updates and collaboration

e. What can policymakers, businesses, and citizens do today?

POLICYMAKERS

- Support deeper research on the impacts of microfiber pollution
- Support cross-sector efforts to encourage alignment and collaboration
- Work with industry to develop effective legislation to advance solutions
- Recognize that there is not one solution and take many approaches

BUSINESSES

- Continue to support research impacts of microfiber pollution
- Support cross-sector efforts to encourage alignment and collaboration
- Design products to shed less and last longer
- Encourage collaboration between companies and non-profits, both on communication and research

CITIZENS

- Know what's in your closet, look at care and content labels
- Buy from brands actively engaged in microfiber pollution issue
- Ask your favorite brands and legislators to take a deeper role in developing solutions
- Follow the Simple Tips by Ocean Wise: Wash less, say no to "fast fashion", change wash conditions, and install a microfiber filter (see Figure 7)

f. What are the priorities in research, connection, and innovation?

These are the top priorities that were identified during the workshop:

RESEARCH

- Supporting more regional studies that document microfiber pollution in the natural environment and identify sources of microfiber pollution and likely pathways (including air and terrestrial)
- Supporting research on impacts of fiber and textile chemistry on soil, plant, and biota
- Supporting research to understand degradability of a range of material types in a range of environments, with priority on the marine environment
- Supporting research for additional assessment of potential source pathways from non-apparel sectors

CONNECTION

- Supporting additional multi-stakeholder workshops that evaluate a range of microfiber pollution solutions (such as filtration options and defining biodegradability as it relates to innovation) to continue the development of shared understanding and solution prioritization
- Organizing microfiber-specific interest groups (i.e., develop a California Microfiber Coalition) where stakeholders are able to stay updated on science, share information, and discuss available solutions
- Bringing industry professionals and policymakers out of the office to engage with scientists in the field for experiential learning programs to encourage deeper connectivity and creativity (i.e., lab visits, research day sails, research site visits, etc.)
- Encouraging industry cross-sharing of immediate solutions with existing technology that can be implemented (i.e., solution dyeing, garment washing, textile construction changes, etc.)
- Collaborating on global test method development and alignment to ensure ease of adoption and implementation once ready

INNOVATION

- Exploring filtration as an immediate solution as design change solutions are identified
- Supporting and sharing innovation challenges, such as the Conservation X Labs Microfiber Innovation Challenge
- Joining and/or supporting existing cross-sector global efforts such as The Microfibre Consortium and The Microfiber Partnership through the Ocean Wise Research Institute to review best existing cross-textile industry data and integrate soon-to-be-developed product development recommendations
- Shifting product design to systems-thinking with circularity and natural systems in mind
- Working collaboratively to design extended producer responsibility policy frameworks that reward companies leading efforts, incentivize better design, and decentivize low quality, high quantity fast fashion

References

Barrows, A., Cathey, S.E., Petersen, C.W., (2018). Marine environment microfiber contamination: global patterns and the diversity of microparticle origins. *Environmental Pollution* 237, 275-284. https://doi.org/10.1016/j.envpol.2018.02.062

Box, C., (2020, November 19). *California microfiber workshop: science, innovation & connection [Conference Workshop].* California Microfiber Workshop. https://www.materevolve.com/events/ef4uw725z4f7yjjw1g3r8ecv52pvtq

Box, C., Cummins, A., (2019). *San Francisco bay microplastics study: science-supported solutions and policy recommendations* (SFEI Contribution No. 955). The 5 Gyres Institute. https://www.sfei.org/documents/sf-bay-microplastics-solutions

Coffin, Scott, (2020, November 19). *NOAA microfibers workshop: state water board perspective*. [Conference Workshop]. California Microfiber Workshop. https://www.materevolve.com/events/ef4uw725z4f7yjjw1g3r8ecv52pvtq

Cotton Incorporated. (2018). *Biodegradability of cotton*. https://www.cottonworks.com/topics/sustainability/cotton-sustainability/biodegradability-of-cotton/#

Eriksen, M., Lebreton, L.C.M., Carson, H.S., Thiel, M., Moore, C.J., Borerro, J.C., Galgani, F., Ryan, P.G., Reisser, J., (2014). Plastic pollution in the world's oceans: more than 5 trillion plastic pieces weighing over 250,000 tons afloat at sea. *PLoS ONE* 9, e111913. https://doi.org/10.1371/journal.pone.0111913

Gavigan, J., Kefela, T., Macadam-Somer, I., Suh, S., Geyer, R., (2020). Synthetic microfiber emissions to land rival those to waterbodies and are growing. *PLoS ONE* 9, e0237839. https://doi.org/10.1371/journal.pone.0237839

Hartline, N.L., Bruce, N.J., Karba S.N., Ruff, E.O., Sonar, S.U., Holden, P.A., (2016). Microfiber masses recovered from conventional machine washing of wew or aged garments, *Environmental Science & Technology* 50, 11532-11538.

Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R., Law, K.L., (2015). Plastic waste inputs from land into the ocean. *Science* 347, 768–771. https://doi.org/10.1126/science.1260352

Kapp, K.J., Miller, R.Z., (2020). Electric clothes dryers: An underestimated source of microfiber pollution. *PLoS ONE* 15, e0239165. https://doi.org/10.1371/journal.pone.0239165

Karba, S., (2020, November 19). *Patagonia microfiber update*. [Conference Workshop]. California Microfiber Workshop. https://www.materevolve.com/events/ef4uw725z4f7yjjw1g3r8ecv52pvtq

McIlwraith, H.K., Lin, J., Erdle, L.M., Mallos, N., Diamond, M.L., Rochman, C.M., (2019). Capturing microfibers – marketed technologies reduce microfiber emissions from washing machines. *Marine Pollution Bulletin* 139, 40–45. https://doi.org/10.1016/j.marpolbul.2018.12.012

The Nature Conservancy, (2020, October 16). *New microplastics study as many as 4,000 metric tons of synthetic microfibers pollute California environment per year [Press release]*. https://www.nature.org/en-us/newsroom/california-microplastics/#

O'Brien, S., Okoffo, E.D., O'Brien, J.W., Ribeiro, F., Wang, X., Wright, S.L., Samanipour, S., Rauert, C., Toapanta, T.Y., Albarracin, R., Thomas, K.V., (2020). Airborne emissions of microplastics fibers from domestic laundry dryers. *Science of Total Environment* 747, 141175. https://doi.org/10.1016/j.scitotenv.2020.141175.

Rochman, C.M., Lewison, R.L., Eriksen, M., Allen, H., Cook, A.-M., Teh, S.J., (2014). Polybrominated diphenyl ethers (PBDEs) in fish tissue may be an indicator of plastic contamination in marine habitats. *Science of The Total Environment* 476–477, 622–633.

Royer, S.J., (2020, November 19). *Plastic pollution and microfiber in the environment*. [Conference Workshop]. California Microfiber Workshop. https://www.materevolve.com/events/ef4uw725z4f7yjjw1g3r8ecv52pvtq

San Francisco Estuary Institute (2019). *The pulse of the bay: pollutant pathways* (SFEI Contribution No. 954). San Francisco Estuary Institute. https://www.sfei.org/documents/2019-pulse-bay-pollutant-pathways

Suaria, G., Achtypi, A., Perold, V., Lee, J.R., Pierucci, A., Bornman, T.G., Aliani, S., Ryan, P.G., (2020). Microfibers in oceanic surface waters: a global characterization. *Science Advances* 6 (23). https://doi.org/10.1126/sciadv.aay8493

Sutton, R., Lin, D., Sedlak, M., Box, C., Franz, A., Gilbreath, A., Holleman, R., Miller, E., Adam Wong, Munno, K., Zhu, X., Rochman, C., (2019). *Understanding microplastic levels, pathways, and transport in the San Francisco Bay region* (SFEI Contribution No. 950). San Francisco Estuary Institute, https://www.sfei.org/documents/understanding-microplastics

Vassilenko, K., M. Watkins, S. Chastain, A. Posacka and P.S. Ross. (2019). *Me, my clothes and the ocean: the role of textiles in microfiber pollution*. Ocean Wise Conservation Association. https://assets.ctfassets.net/fsquhe7zbn68/4MQ9y89yx4KeyHv9Svynyq/8434de64585e9d2cfbcd3c46627c7a4a/Research_MicrofibersReport_191004-e.pdf

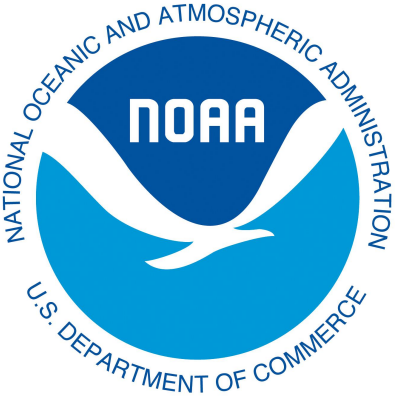
Vassilenko, E.K., Watkins, M., Mertens, J., Posacka, A.M., Patankar, S., Ross, P.S. (2021). Domestic laundry and microfiber pollution: exploring fiber shedding from consumer apparel textiles. Under review in *PLoS ONE*.

Zambrano, M., Pawlak, J., Daystar, J., Ankeny, M., Cheng, J., Venditti, R. (2019). Microfibers generated from the laundering of cotton, rayon and polyester based fabrics and their aquatic biodegradation. *Marine Pollution Bulletin* 142, 394-407. https://doi.org/10.1016/j.marpolbul.2019.02.062.

Zambrano, M, Pawlak, J., Daystar, J., Ankeny, M., Goller, C., Venditti, R. (2020). Aerobic biodegradation in freshwater and marine environments of textile microfibers generated in clothes laundering: Effects of cellulose and polyester-based microfibers on the microbiome. *Marine Pollution Bulletin* 151, 110826. https://doi.org/10.1016/j.marpolbul.2019.110826.

Other Relevant Workshop Resources

California Microfiber Workshop Agenda:
https://www.materevolve.com/events/ef4uw725z4f7yjjw1g3r8ecv52pvtq



National Marine Sanctuary Foundation

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Association of Home Appliance Manufacturers (AHAM)
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Archroma
As You Sow
Bolt Threads
California Product Stewardship Council
California State University Channel Islands
Casper
Conservation X Labs
Cotton Incorporated
Coyuchi
DRI
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What materials legacy do you want to leave?

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