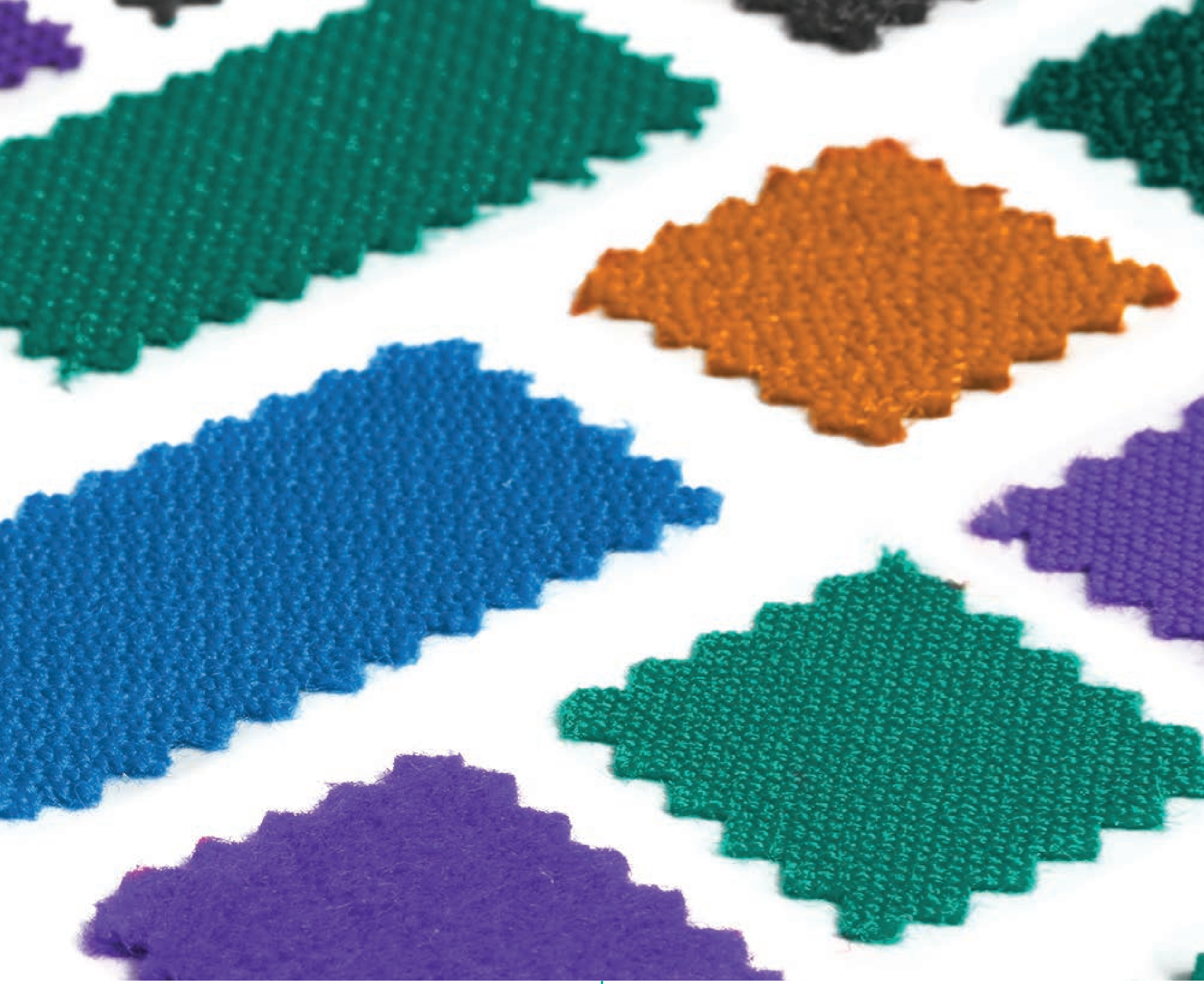


OCEAN WISE SCIENCE FEATURE

Me, My Clothes and the Ocean

THE ROLE OF TEXTILES IN MICROFIBER POLLUTION

Prepared by Katerina Vassilenko, Mathew Watkins, Stephen Chastain, Anna Posacka and Peter S. Ross

ocean wise.

Executive Summary

Microfibers are increasingly common in the world's oceans. However, the material identities, sources, environmental fate and impacts on aquatic life of these particles are not well understood. Microfibers in the ocean may include synthetic and natural fibers originating from multiple sources, but research is increasingly pointing to shedding of textiles in home laundry as one important source. This report presents a summary of findings from the first phase of research carried out by a novel partnership with industry and government agencies led by the Ocean Wise *Plastics Lab*. This *Microfiber Partnership* evaluated the shedding properties of 38 textile samples using a custom-designed washing machine test facility and a dedicated high-resolution analytical laboratory. This work is part of a wider initiative to characterize the identity, fate and effects of microplastics in the world's oceans. Results revealed a surprisingly wide range in the degree to which different textiles shed in a single wash, ranging from a loss of 9.6 mg to 1,240 mg, or an estimated 9,777 to 4,315,371 microfibers, per kg of textile washed. Most textiles lost more microfibers in an initial wash compared to subsequent washes. Polyester textile samples, dominated by mechanically treated polyester fleeces and jerseys, shed the most (average of 161 ± 184 mg per kg of textile per wash), compared to nylon textiles with filament-type yarns and a woven construction (average of 27 ± 16 mg per kg of textile per wash). Interestingly, cotton and wool textiles also shed large amounts of microfibers (average of 165 ± 44 mg per kg of textile per wash). Textile properties including construction, yarn type, mechanical treatment and chemical finish likely explain differences in shedding among the materials tested, highlighting the value of additional applied research. We estimate that the average household in Canada and the U.S. releases 533 million microfibers – or 135 g – from laundry into the wastewater treatment system every year, with a collective release of 3.5 quadrillion (3.5×10^{15}) microfibers – or 878 tonnes – following wastewater treatment to the aquatic environment (freshwater and ocean). That extent of microfiber release through untreated wastewater remains unclear. The results of this research can contribute to more sustainable textile design, best practices, wastewater engineering opportunities, and consumer choices.

About the Microfiber Partnership

In 2017, the Ocean Wise *Plastics Lab* launched the *Microfiber Partnership*, a solution-oriented research initiative that brings together researchers, the apparel industry, and government agencies concerned about the sources and impacts of microfiber pollution in the ocean. Central to this research initiative was the design of a dedicated washing machine test facility, the development of new methods to sample liquid laundry effluent and municipal wastewater, and the characterization of microfiber samples using microscopic image analysis and Fourier Transform Infrared Spectrometer (FTIR).

The Phase 1 research objectives of the *Microfiber Partnership* addressed three elementary topics:

- Home laundry as a source of microfibers in the environment;
- Retention, fate and discharge of microfibers in a secondary wastewater treatment plant;
- Forensic methods for the identification of textile microfibers following weathering in air, seawater and wastewater.

IN PARTNERSHIP WITH

This project was undertaken with the financial support of:
Ce projet a été réalisé avec l'appui financier de :
Environment and Climate Change Canada / Environnement et Changement climatique Canada

Introduction

Synthetic microfibers are common and are widely distributed in the ocean environment[1-4]. They represent a concern because of their significant contribution to environmental microplastics[3,5] – small plastic pollutants (5 mm - 1 μm in length) that can come from a variety of sources, such as breakdown of large plastic litter or microbeads in cosmetic care products. Microfiber shedding from textiles during home laundry and their incomplete removal by Wastewater Treatment Plant (WWTP) processes are thought to play a role in releasing fibers to the aquatic environment. For instance, a single garment can release 120-730,000 microfibers in a laundry cycle[6-8]. Our recent research suggests that approximately 60% of the 30 billion microplastics emitted annually by a secondary treatment facility in Vancouver, British Columbia (BC), Canada[9] are microfibers, with additional evidence from other studies pointing to an abundance of synthetic particles in wastewater effluent[10].

Reports of microplastic pollution are troubling, because they may be mistaken for food by biota. We previously reported the ingestion of microplastics by two keystone zooplankton species in the Northeast Pacific Ocean[11], while others have reported microplastics in the stomachs of fish[12] and marine mammals[13]. There is significant risk of a legacy for future generations, with plastics having the potential to persist for a long time[14]. Since cleanup at sea is unlikely to be able to effectively reduce the overall level of plastic pollution in the ocean, action at source will be key to reducing discharge of plastics, including the microfibers, into the receiving environment. However, microfiber pollution science is a relatively new area, and a relative lack of comprehensive data is hampering the development and implementation of suitable mitigation strategies for microfibers.

We launched the *Microfiber Partnership* in 2017 with apparel firms MEC, Patagonia, REI and Arc'teryx, as well as Metro Vancouver and Environment and Climate Change Canada, to better understand the role of textile and home laundry in the release of microfibers into the ocean. As part of this Phase 1 research, we studied a variety of textiles at our custom-built washing machine test facility in Vancouver to better understand the factors underlying the production of microfibers. Since only a handful of textile materials have been examined in previous research, our goal was to generate a wider dataset on the microfiber footprint of different fabrics. We tested textiles constructed with polyester (19), nylon (10), and natural (4) and mixed fibers (4).

Fabrics evaluated here varied in construction and finishing, features we determined to be fundamental to influence shedding. For example, polyester fleeces have their surfaces mechanically treated to create warmth, but this may render the textile more vulnerable to shedding as it creates loose fibers on the product's surface. On the other hand, lightweight and durable nylon textiles are characterized by filament yarns, no mechanical treatment and a smooth surface, and are therefore likely to lose fewer fibers.

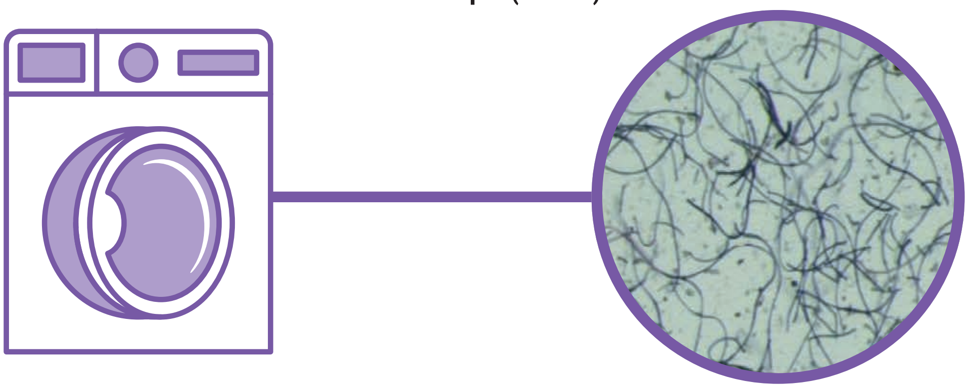
Clothing lies at the heart of this study. And while researchers are adept at identifying and characterizing problems, solutions often feel less tangible, more distant, and difficult to achieve. Our overall hope is that these findings provide a conduit to solutions at multiple levels, be these consumer decisions, green design by the apparel sector, wastewater treatment plant construction, or government leadership. In this light, we as individuals all have a chance to step up and stem the release of microfibers into the environment.

THE PROBLEM

Microfibers Were Detected in Laundry Effluent, Wastewater and Seawater

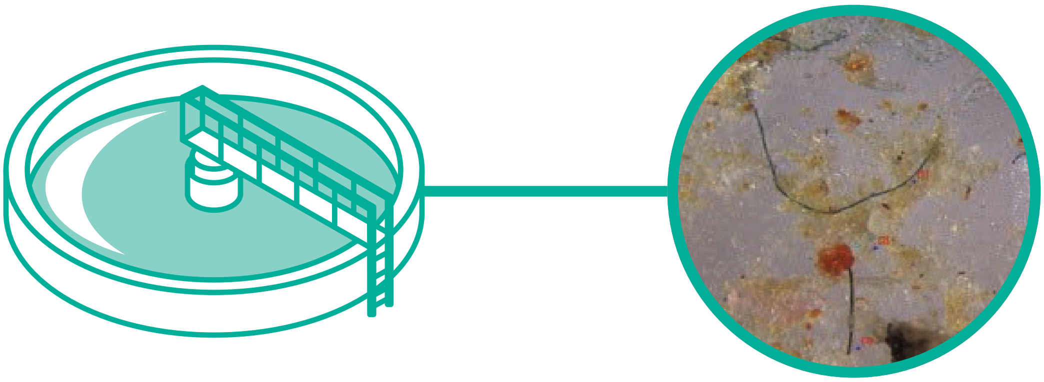
Home Laundry

Effluent Sample (Fleece)



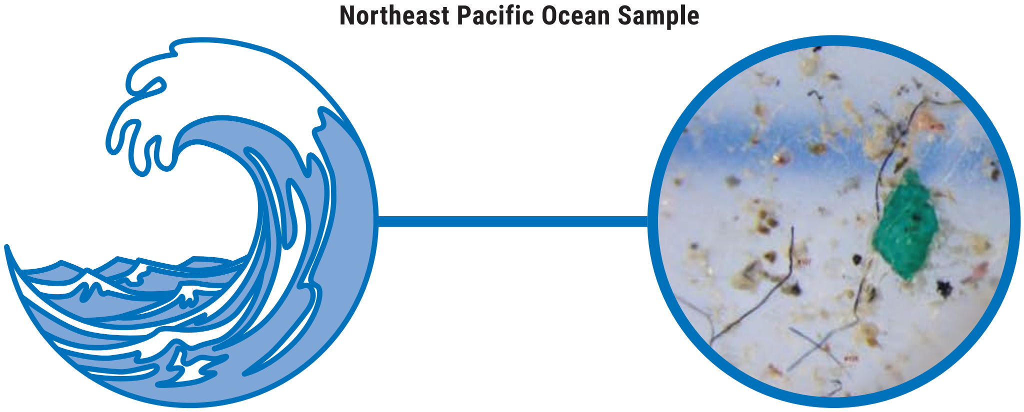
Wastewater Treatment Plants

Final Effluent Sample



Seawater

Northeast Pacific Ocean Sample



Research Methods

The Ocean Wise *Plastics Lab* designed and built a washing machine test facility in Vancouver, British Columbia, Canada (Fig.1). The facility consists of three industrial grade, top loading washing machines (SDL Atlas M6 Vortex), each equipped with a custom-built collection manifold for subsampling of laundry effluent. The washing machines were contained inside a purpose-built tent to reduce sample contamination by airborne microfibers. All sample processing post-collection was carried out under the HEPA filtered air of the laminar flow hood.

Microfiber shedding was tested for 37 textile samples provided by apparel partners using an adaptation of the AATCC 135-2004 method[15]. Shedding was determined through the determination of mass (mg) and an estimate of the total number of microfibers shed from a textile sample in a single wash. Materials tested varied in terms of their polymer composition (cotton, wool, polyester, nylon, in some cases mixed with spandex or elastane), yarn type (short, spun staple and long, filament yarns), textile construction (knit and woven), mechanical treatment (brushed, sanded or sheared), and chemical treatment (use of anti-piling, softener, wicking, Durable Water Repellent (DWR) and anti-odor chemicals).

Each textile was cut into 26” x 26” squares (66 cm x 66 cm) and their edges were hemmed. Samples were washed five times and microfibers captured using our custom-built subsampling unit. Microfibers were isolated onto 20 µm polycarbonate filters under the laminar flow hood, weighed and enumerated under the microscope. Data in this report is presented as the average microfiber mass shed from the last three washes normalized to 1 kg of the textile. Width, length and physical appearance of fibers were determined using microscopic image analysis, and additional characterization involved the use of Fourier Transform Infrared Spectrometer (FTIR) technology.

Annual estimates of synthetic microfiber pollution generated by home laundry in Canada and the U.S. and discharged to the aquatic environment via wastewater treatment plants were derived. Estimates were obtained using the average microfiber shedding by weight (131 mg per kg of textile per wash) and count (514,398 microfibers per kg of textile per wash) by all fabrics from this study. Data was converted to a weight of a domestic laundry load (4 kg). Natural fabrics were excluded from our estimate.

The annual total household production of microfibers from laundry is based on the value of 14,072,080 Canadian households (Statistics Canada, 2017)[16] and an average of 218 laundry loads per year per household (Natural Resources Canada, 2011)[17]. For the U.S., annual household microfiber production was calculated using a value of 127,586,000 households (U.S. Census Bureau, Current Population Survey, 2018)[18] and an assumed 300 laundry loads per household per year (https://www.nps.gov/articles/laundry.htm).

To estimate microfiber emission via wastewater we assumed a 95% retention in facilities based on international scientific data on microplastics in Wastewater Treatment Plants (WWTPs)[9,10], based on research on primary, secondary and tertiary wastewater facilities. These estimates take into account the proportion of domestic wastewater that is untreated or collected into household septic tanks in Canada (16%, Environment Canada, 2017)[19] and the U.S. (19%, Center for Sustainable Systems, University of Michigan. 2018. “U.S. Wastewater Treatment Factsheet.” Pub. No. CSS04-14)[20].

Figure 1. Washing Machine Test Facility in Vancouver, BC, Canada.

METHODS

How Do We Test Textiles for Microfiber Shedding in Laundry?

Researchers from the Ocean Wise *Plastics Lab* established a test facility and developed protocols to capture microfibers shed from a textile in a typical domestic wash.

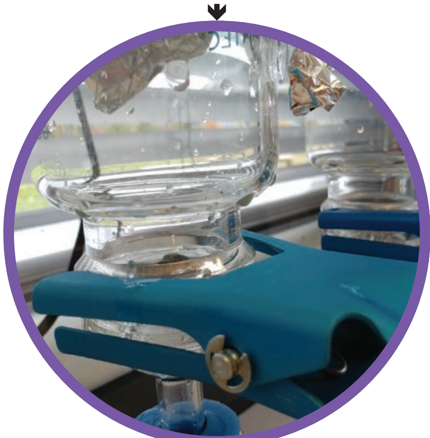
WASHING MACHINE TEST FACILITY, VANCOUVER, BC

01 Wash Fabrics

Using standard domestic washing machines and conditions mimicking typical home laundry.

02 Sample Effluent

Subsample 10 L of laundry effluent with a custom-built collection unit.



03 Filter Effluent

In the laminar flow hood, separate microfibers from laundry effluent onto 20 μm filter.

04 Weigh + Count

After drying in the oven, weigh filters with microfibers. Count and measure their length and width under the microscope.

Results

All textiles shed microfibers during a standard home laundry cycle, but the extent of shedding varied widely among products tested.

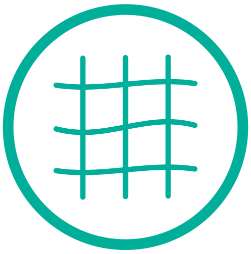
The range of microfiber shedding during a single wash spanned several orders of magnitude, from 9.6 mg to 1,240 mg of microfibers, or an estimated 9,766 to 4,315,371 microfibers per kg of textile per wash. Up to 0.16% of the mass of a textile sample was lost every time it was washed.

Microfiber shedding varied with repeat washing. In general, shedding was highest in the initial wash compared to subsequent washes. For the majority of samples, shedding leveled off after the third wash.

The density of the textile tested played a role in shedding, with thicker fabrics releasing more microfibers. Polyester materials tended to lose more microfibers with increasing textile density, compared to nylon materials.

Textile Design Features and Microfiber Shedding

Textile properties can influence the degree of microfiber shedding during domestic laundry.



Construction

The choice of woven or knit textile design may limit or increase shedding.

Yarn Type

Filament or spun staple textile designs underlie the length of fabric fibers, a key factor in microfiber release.

Mechanical Treatment

Mechanically treating a fabric can render the surface vulnerable to shedding, as it partially or fully breaks the surface filaments.

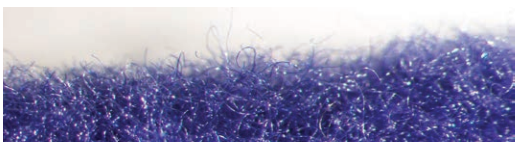
Chemical Treatment

Chemical treatment may affect the release of microfibers.

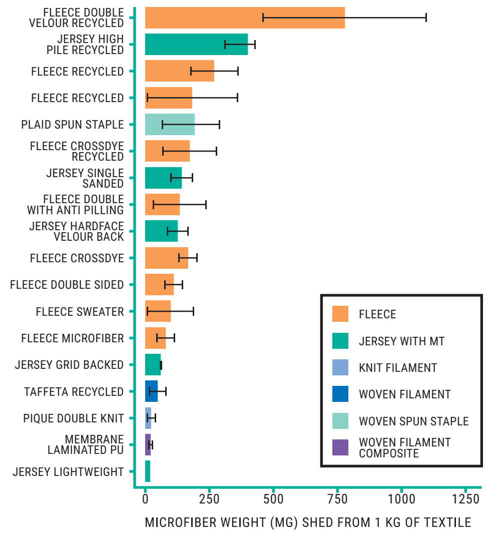
Polyester Textiles

SHEDDING BY POLYESTER TEXTILES VARIED 100-FOLD

- On average, polyester materials shed 161 ± 184 mg of microfibers per kg of textile per wash (19 to 778 mg).
- Most polyester fabrics tested were mechanically-treated fleeces and jerseys.
- Not all polyester fabric samples shed equally, with a 10-fold range in shedding from fleece samples. This suggests that textile design influences microfiber shedding, and this information can be used to create more sustainable textiles. Further tests are underway at the *Plastics Lab* that will further inform how features of textile design influence microfiber shedding.



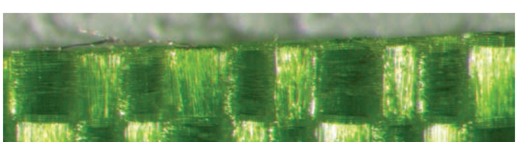
Polyester fleece



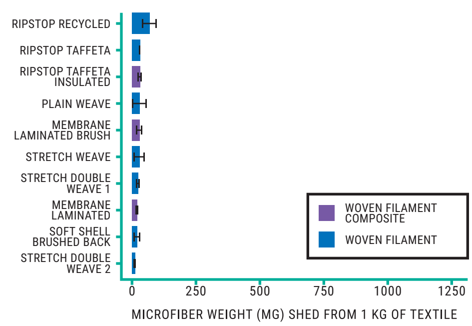
Nylon Textiles

NYLON TEXTILES SHED LITTLE IN COMPARISON

- On average, nylon materials shed 27 ± 16 mg of microfibers per kg of textile per wash (11 mg to 63 mg), significantly less than the polyester fabrics (Kruskal–Wallis test, $p<0.001$).
- Materials in this category consisted of lightweight textiles that have application in waterproof or windproof clothing and abrasion-resistant outdoor gear. All were characterized by having filament-type yarns and woven construction (multiple yarns crossing each other at right angles to form the grain). These design features may help explain the reduced shedding from nylon textiles.



Nylon ripstop

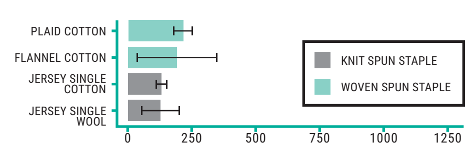


Natural Textiles

NATURAL FIBER TEXTILES ALSO SHED DURING LAUNDRY

- The natural textiles we investigated shed on average 165 ± 44 mg per kg of textile per wash (ranging from 126 to 214 mg) and had shedding rates in the range of polyester-based materials.
- Natural fibers, assumed to originate from textiles, have also been reported in the ocean environment[21]. This raises questions about the microfiber footprint from textiles constructed with natural fibers such as cotton.

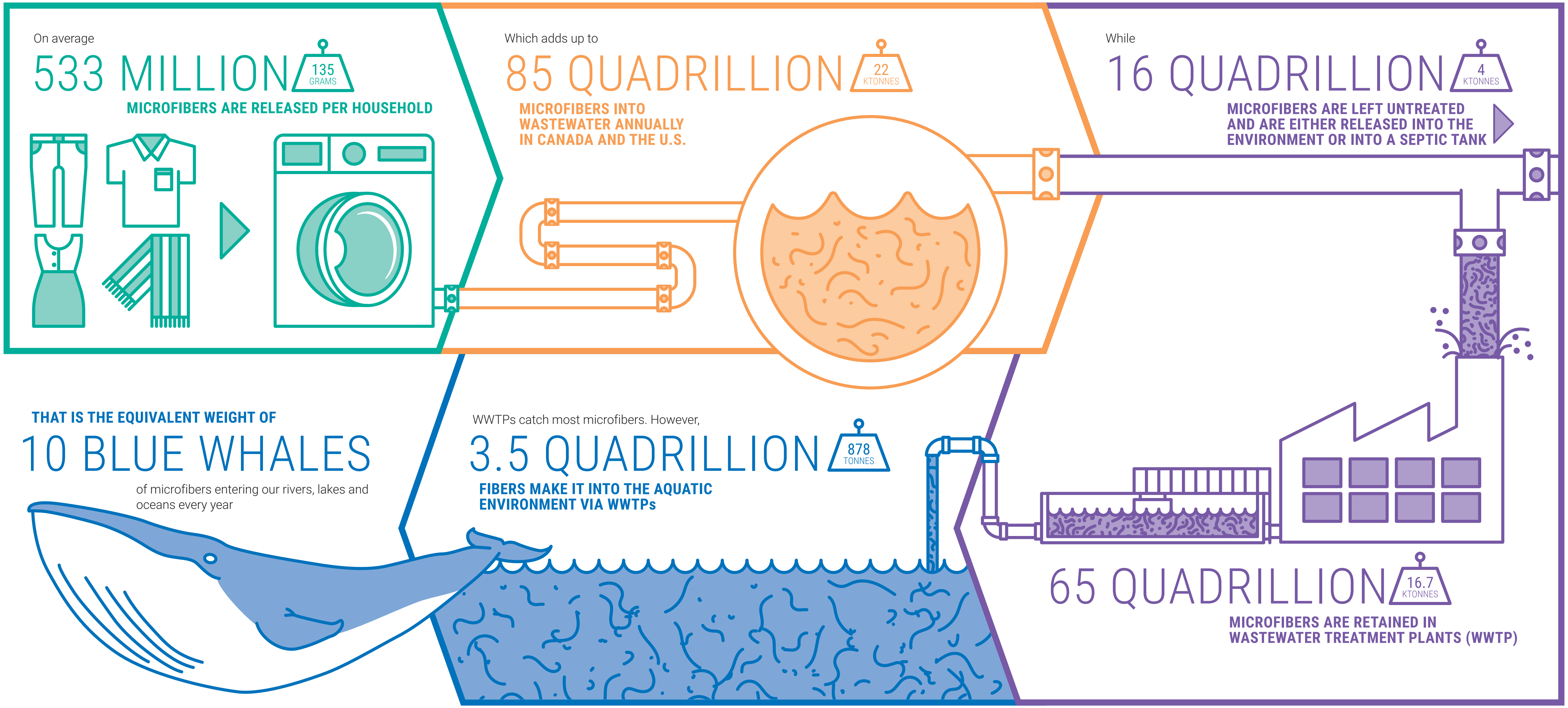
Merino single jersey knit



RESEARCH

Our Research Suggests that Home Laundry of Textiles Releases Large Amounts of Microfibers into the Environment Every Year

Annual estimates of synthetic microfiber pollution generated by home laundry in Canada and the U.S. and discharged to the aquatic environment via wastewater treatment plants.



FOOTNOTE

Annual estimates for Canada are: 1) An average household release of 444 million or 113 g microfibers; 2) Total households release of 6.3 quadrillion or 1.6 ktonnes of microfibers into domestic wastewater; 3) WWTP facilities retention of 5 quadrillion or 1.3 ktonnes of microfibers; 4) Untreated microfiber pollution (directly released or septic) of 1 quadrillion or 0.25 ktonnes; 5) Total household release into the aquatic environment of 0.26 quadrillion or 67 tonnes.

Annual estimates for the U.S. are: 1) An average household release of 617 million or 156 g microfibers; 2) Total households release of 79 quadrillion or 20 ktonnes of microfibers into domestic wastewater; 3) WWTP facilities retention of 61 quadrillion or 15 ktonnes of microfibers; 4) Untreated microfiber pollution (directly released or septic) of 15 quadrillion or 3.8 ktonnes; 5) Total household release into the aquatic environment of 3.2 quadrillion or 811 tonnes.

Conclusions

- There was a wide range within which different fabrics shed microfibers during home laundry.
- Fabric properties influenced the degree to which fibers were lost during home laundry.
- We estimate that the average home in Canada and the U.S. emits 533 million microfibers per year through home laundry.
- Most microfibers are retained during wastewater treatment processes, but municipal wastewater releases as many as 3.5 quadrillion (3.5×10^{15}) microfibers into the freshwater and ocean environments every year in Canada and the U.S.

Questions Arising from this Research

- What specific apparel design features reduce shedding?
- What is the shedding footprint of natural fabrics?
- How does microfiber shedding compare to other environmental impacts associated with the life cycle of textile manufacture and use (e.g. water use, pesticide use, greenhouse gas emissions, chemical treatments)?
- How can industry best evaluate the propensity of its textile designs to shed?
- How many microfibers enter the environment via untreated wastewater effluent?
- To what extent are microfibers causing harm in the environment?

ACTION

Reduce Your Microfiber Pollution with these Simple Tips

01

Wash Less

Does it really need washing?

02

No to “Fast Fashion”

Invest in products made to last.

03

Wash Conditions

Textile shedding can be reduced by using colder water[22] and a front loading machine[23].

04

Microfiber Filter

Installing a lint trap in your washing machine can substantially reduce microfibers going into wastewater treatment plants[24].

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Ocean Wise is a global conservation organization that is committed to improving the health of our oceans. Through aquariums, education, research and digital communications, we directly inspire tens of millions of people to take actions that will benefit our planet. The *Plastics Lab*, an Ocean Wise Research Institute facility, is based in Vancouver, British Columbia, Canada, specializing in microplastic pollution. Established in 2014, the *Plastics Lab* combines urban- and ocean-oriented study designs, laboratory testing and forensic instrumentation to address the sources, transport and fate of microplastics in aquatic environments. The Ocean Wise *Plastics Lab* partners with industry, government agencies, Indigenous communities and academic groups to research microplastic pollution and to guide solutions. The *Plastics Lab* team studies microplastics in home laundry, seawater, municipal wastewater/sewage, zooplankton, mussels, fish, and marine mammals.

Cite this report as: 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. Science Feature. Ocean Wise Conservation Association, Vancouver, Canada, 16 pp.

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