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Breaking it Down:

Cotton's Biodegradability in Aquatic Environments

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Breaking it Down:

Cotton's Biodegradability in Aquatic Environments

From Thread to Threat: Microfibers as Emerging Pollutants

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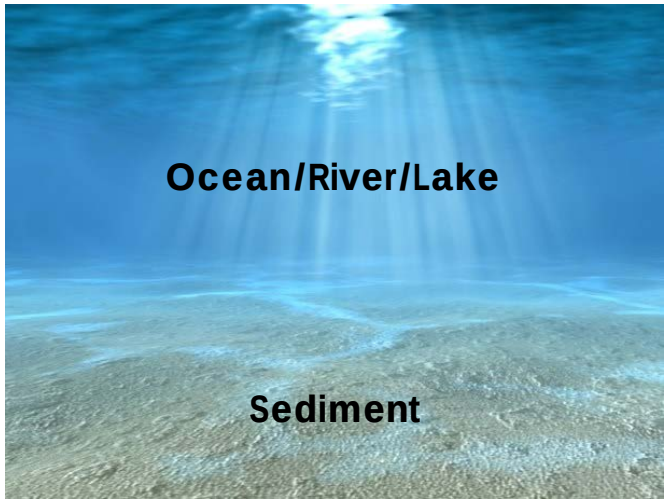
BREN SCHOOL
ENVIRONMENTAL SCIENCE & MANAGEMENT
UNIVERSITY OF CALIFORNIA, SANTA BARBARA

UCSB

Where have they been found?

Salt

Yang et al. (2015)
Karami et al. (2017)



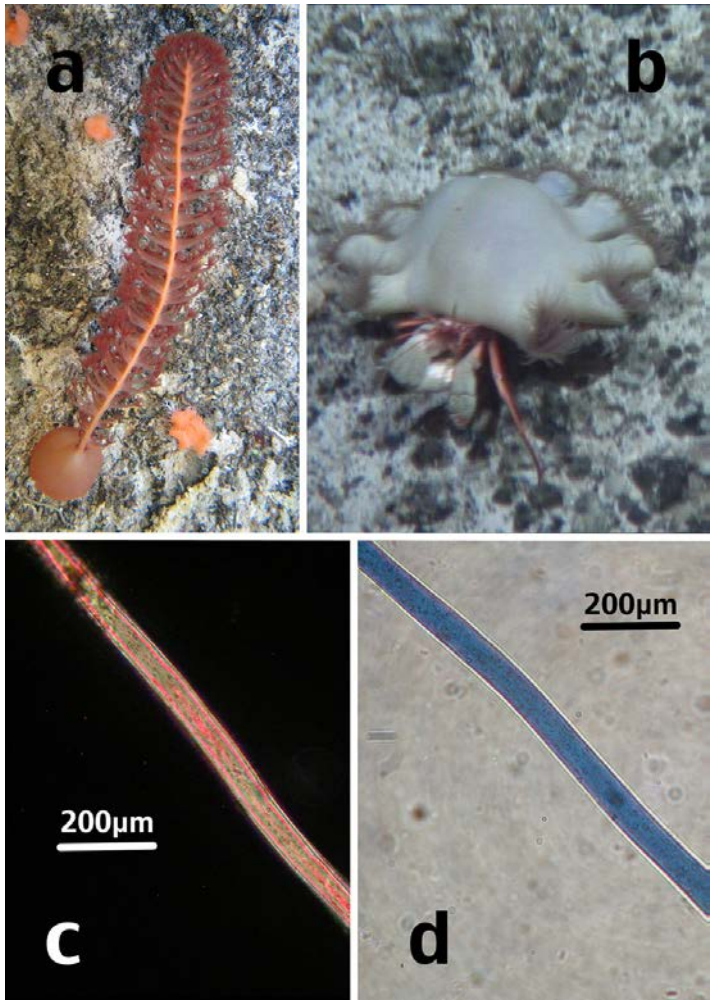
Browne et al. (2011); Miller et al. (2017);
Baldwin et al. (2016)

Sewage Sludge

Mahon et al. (2017)

Arctic Ice

Obbard et al. (2014)

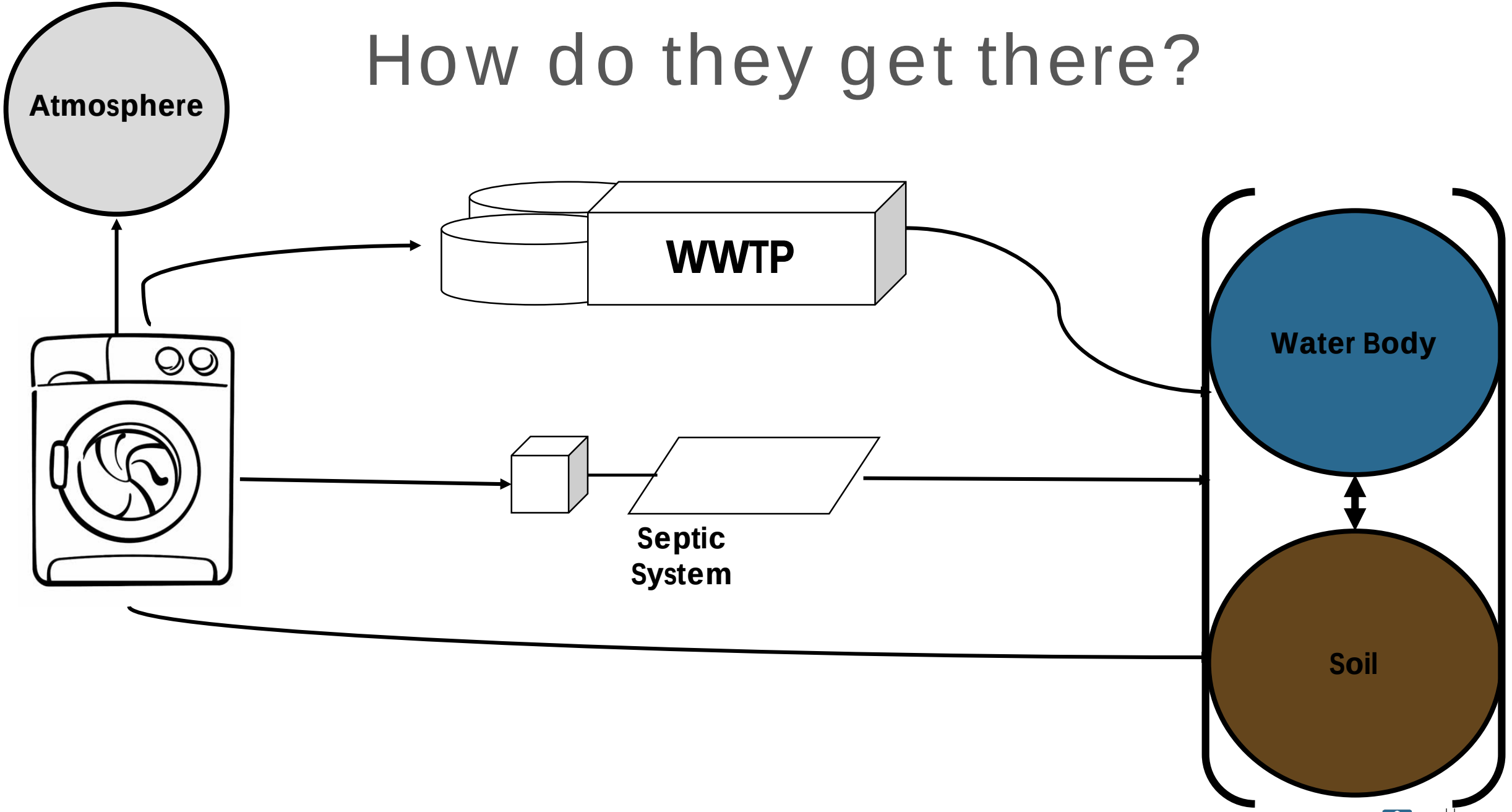


Inside Organisms

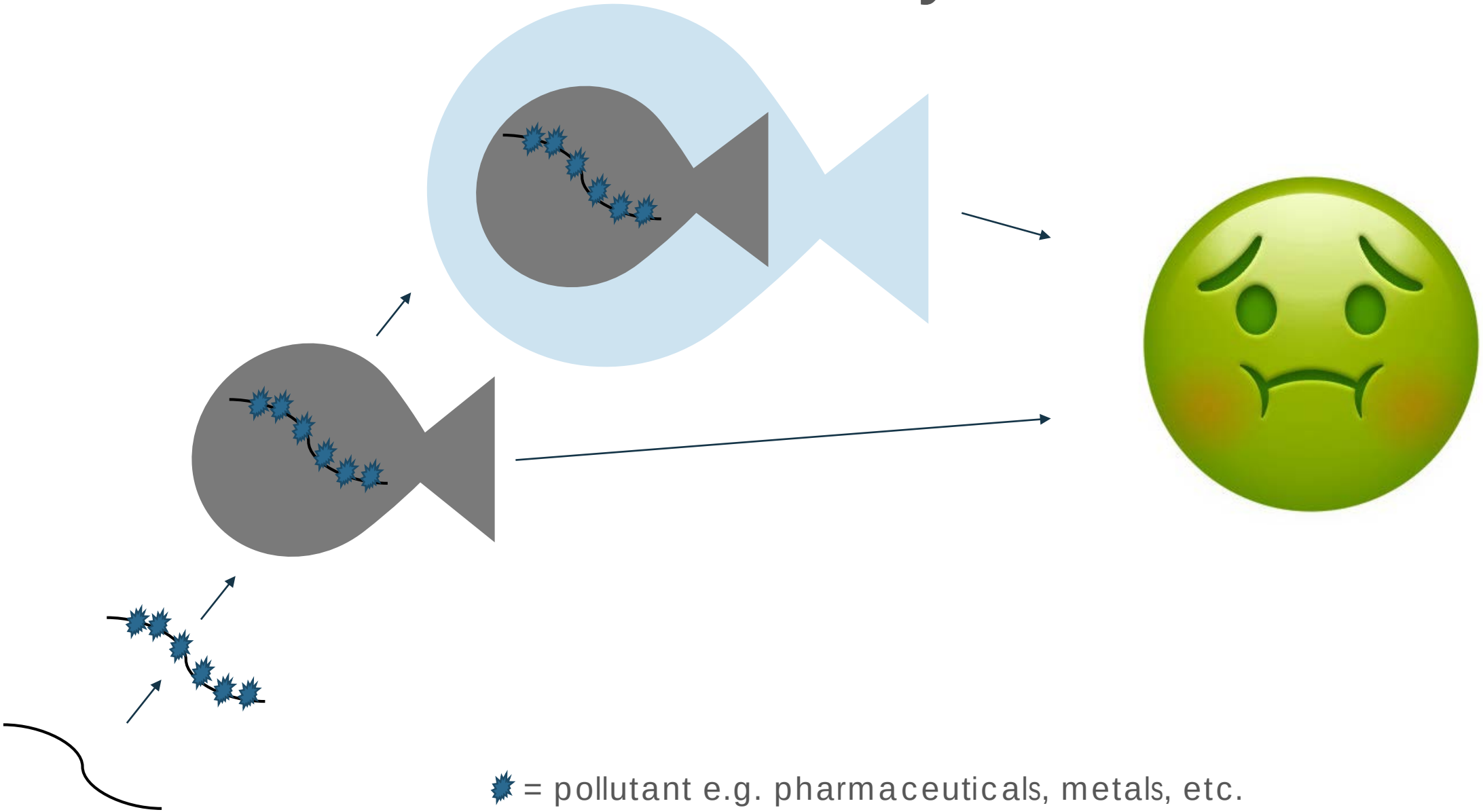
Taylor et al. (2015)

Karami et al. (2017), *Sci Rep*, 46173; Yang et al. (2015), *Environ Sci Technol*, 49(22):13622-13627, Taylor et al. (2015), *Sci Rep*, 6:33997; Obbard et al. (2014), *Earth's Future*, 2:315-320; Browne et al. (2011) *Environ Sci Technol*, 45(21):9175-9179; Miller et al. (2017) *Mar Poll Bull, 124(1):245-251;* Baldwin et al. (2016) *Environ Sci Technol,* 50(19):10377-10385*; Browne et al. (2011) Environ Sci Technol*, 45(21):9175-9179; Mahon et al. (2017) *Environ Sci Technol*, 51(2):810-818.

How do they get there?

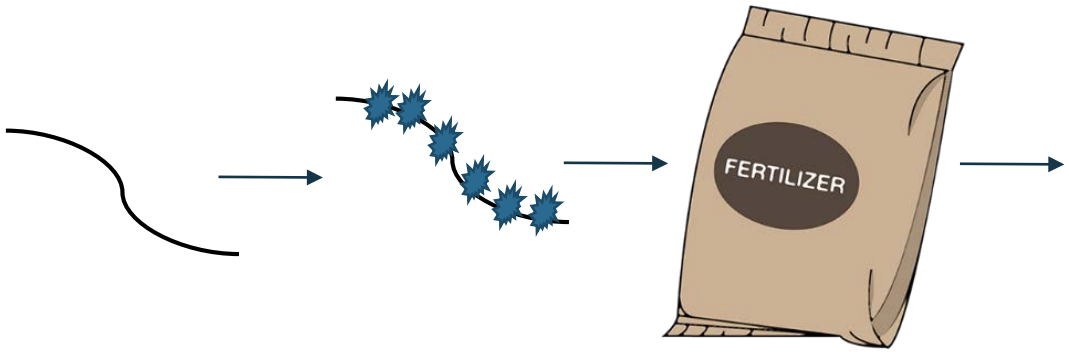


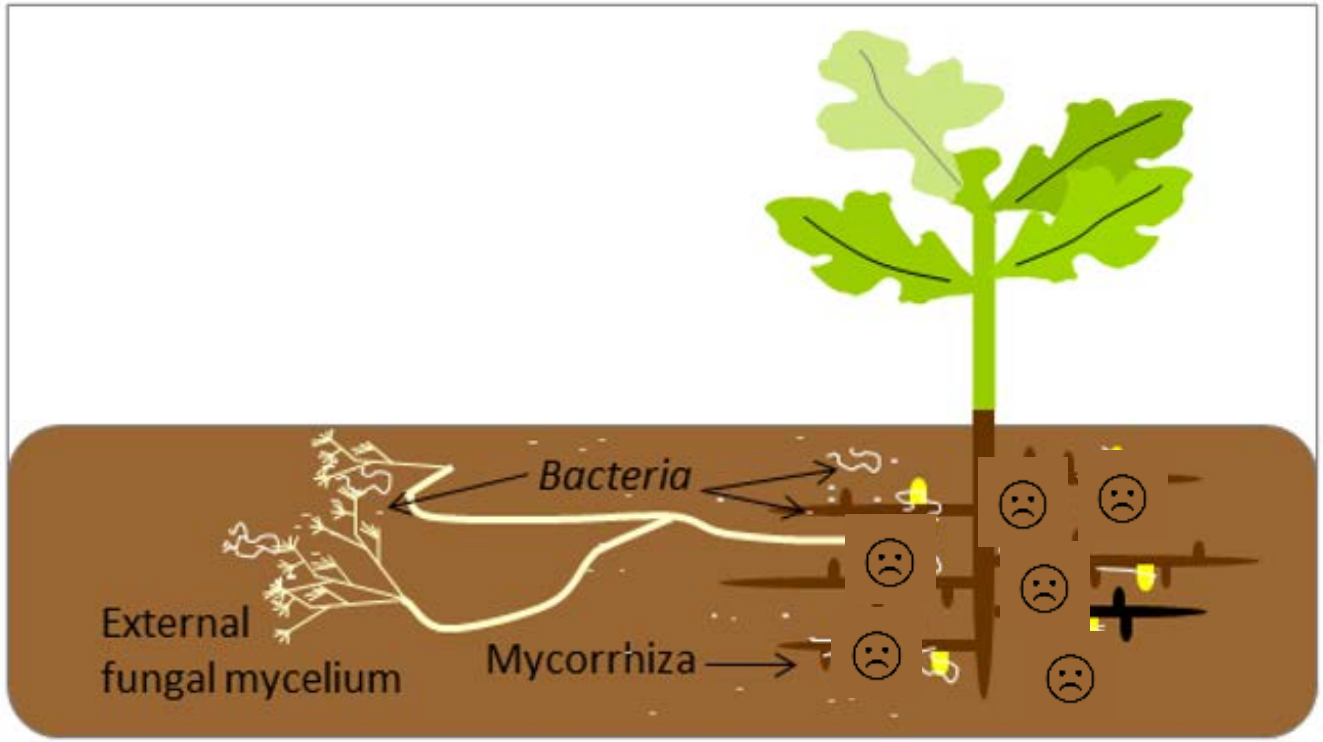
What can they do?



= pollutant e.g. pharmaceuticals, metals, etc.

What can they do?

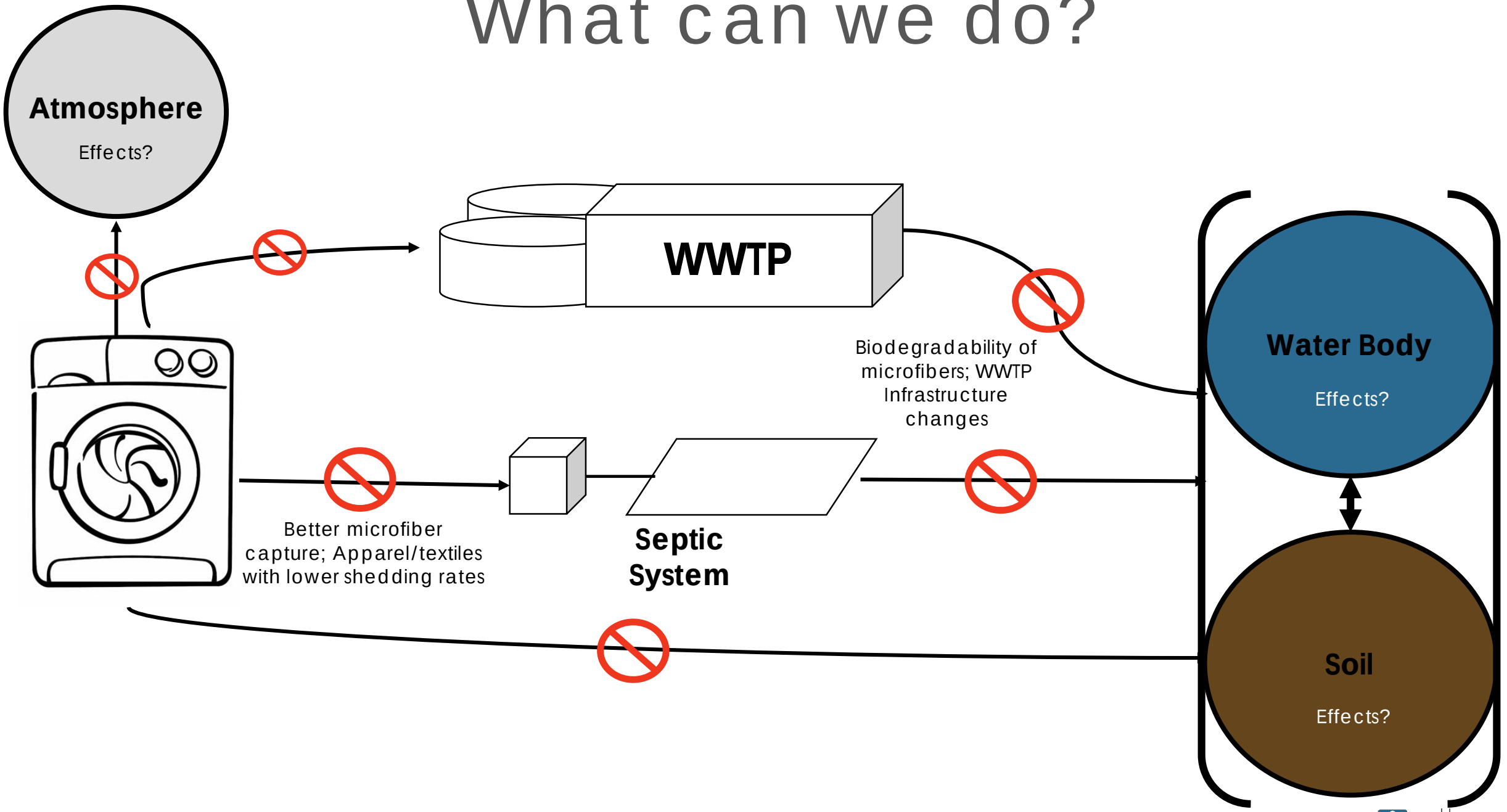




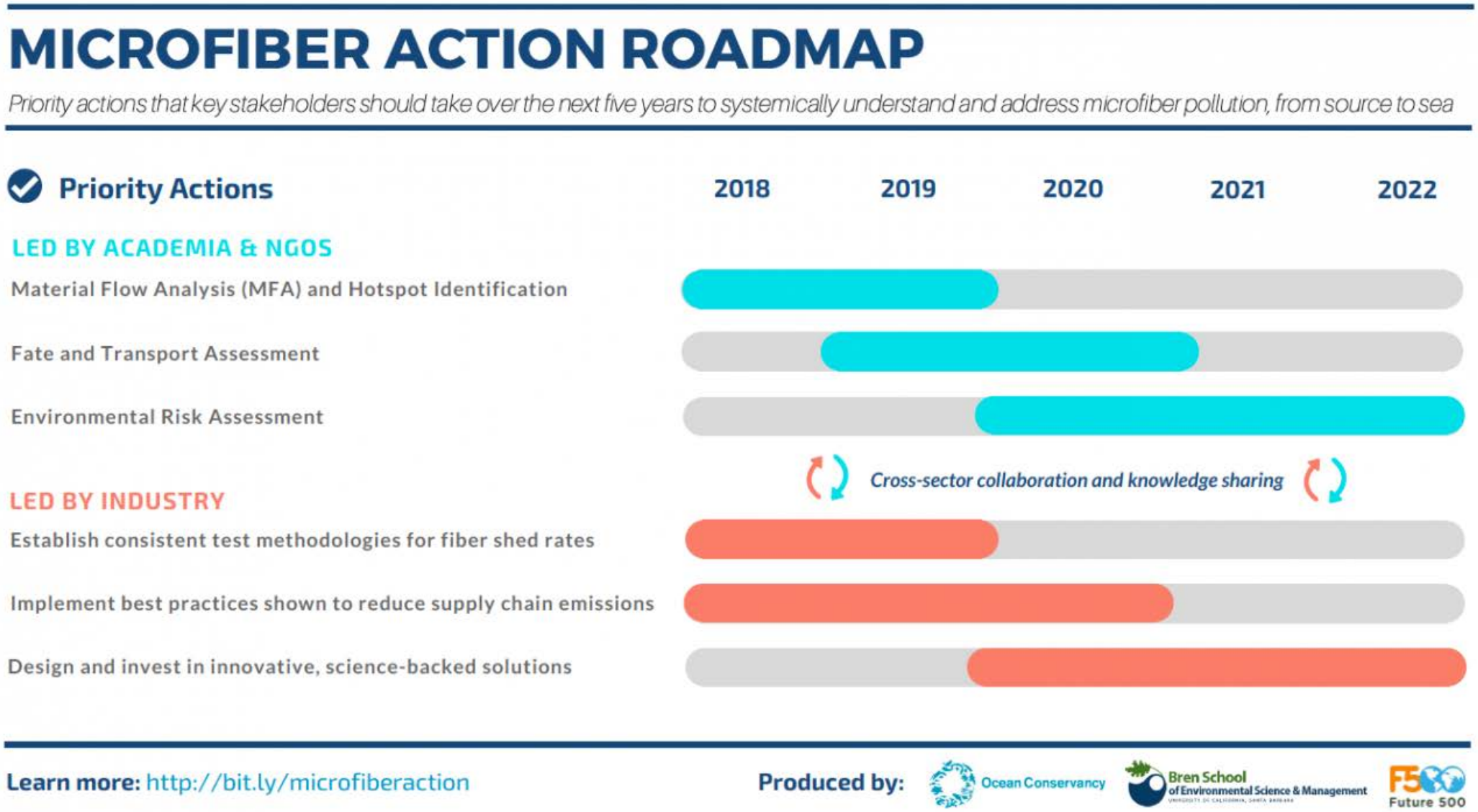
https://www.ufz.de/index.php?en=38915

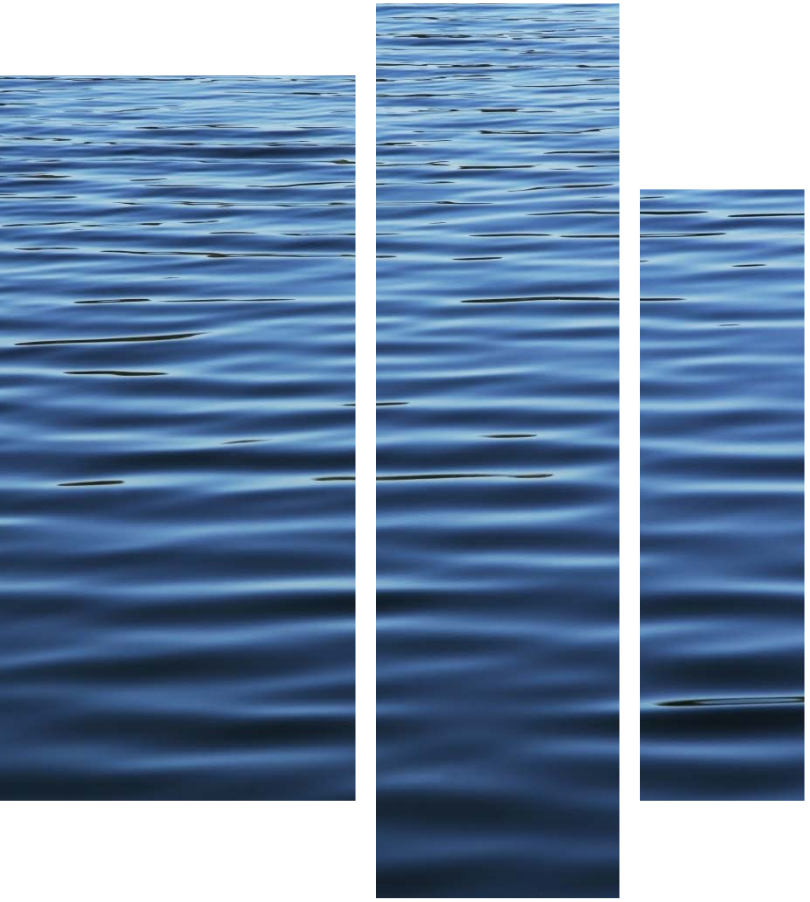
= pollutant e.g. pharmaceuticals, metals, etc.

What can we do?



What can we do?





Microfibers Generated from Laundering of Cotton and Other Fabrics

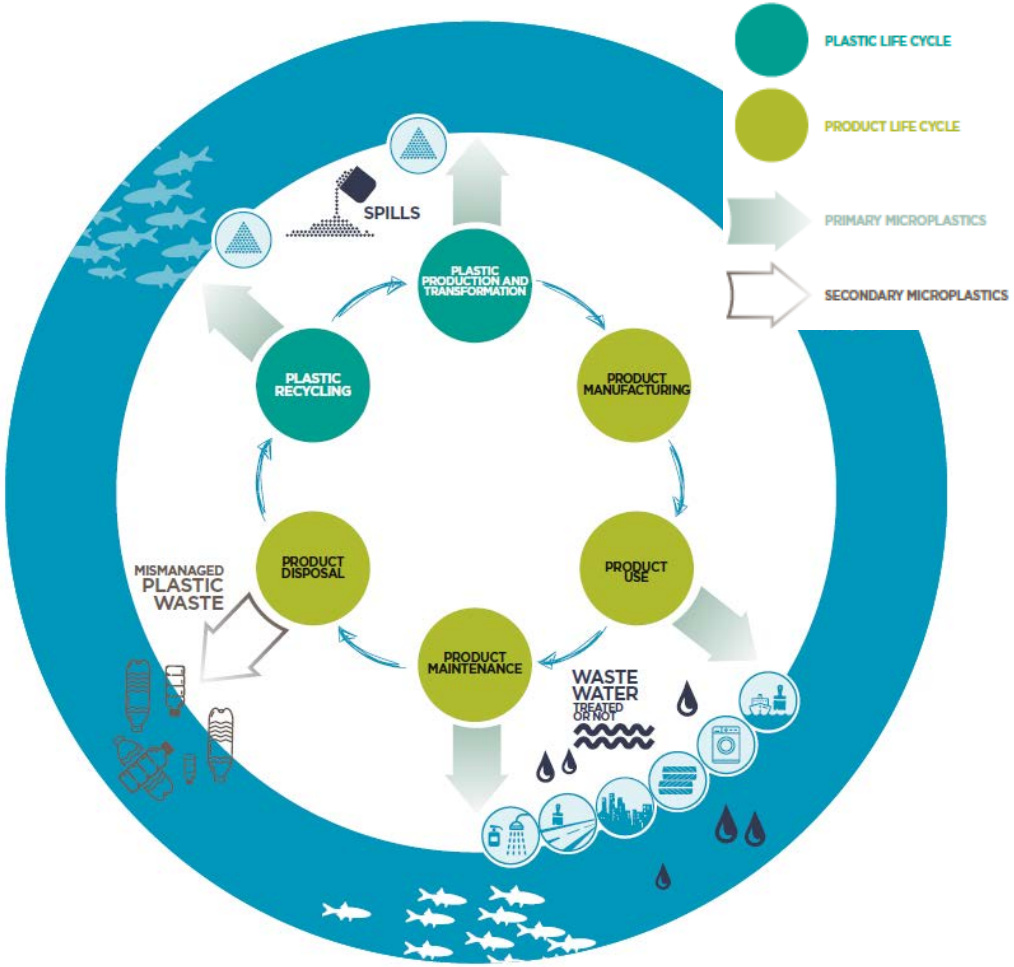
Marielis Zambrano
Richard Venditti, Joel Pawlak, Jesse Daystar, Mary Ankeny, Jay Chen

Outline

- Objectives
- Introduction
- *Microfibers Generation*
  - Accelerated Laundering Experiments
  - Results
  - Summary
- *Aquatic Biodegradability of Textile Yarns*
  - Experimental Methodology
  - Results
  - Summary
- Conclusions
- Next Steps

Objectives

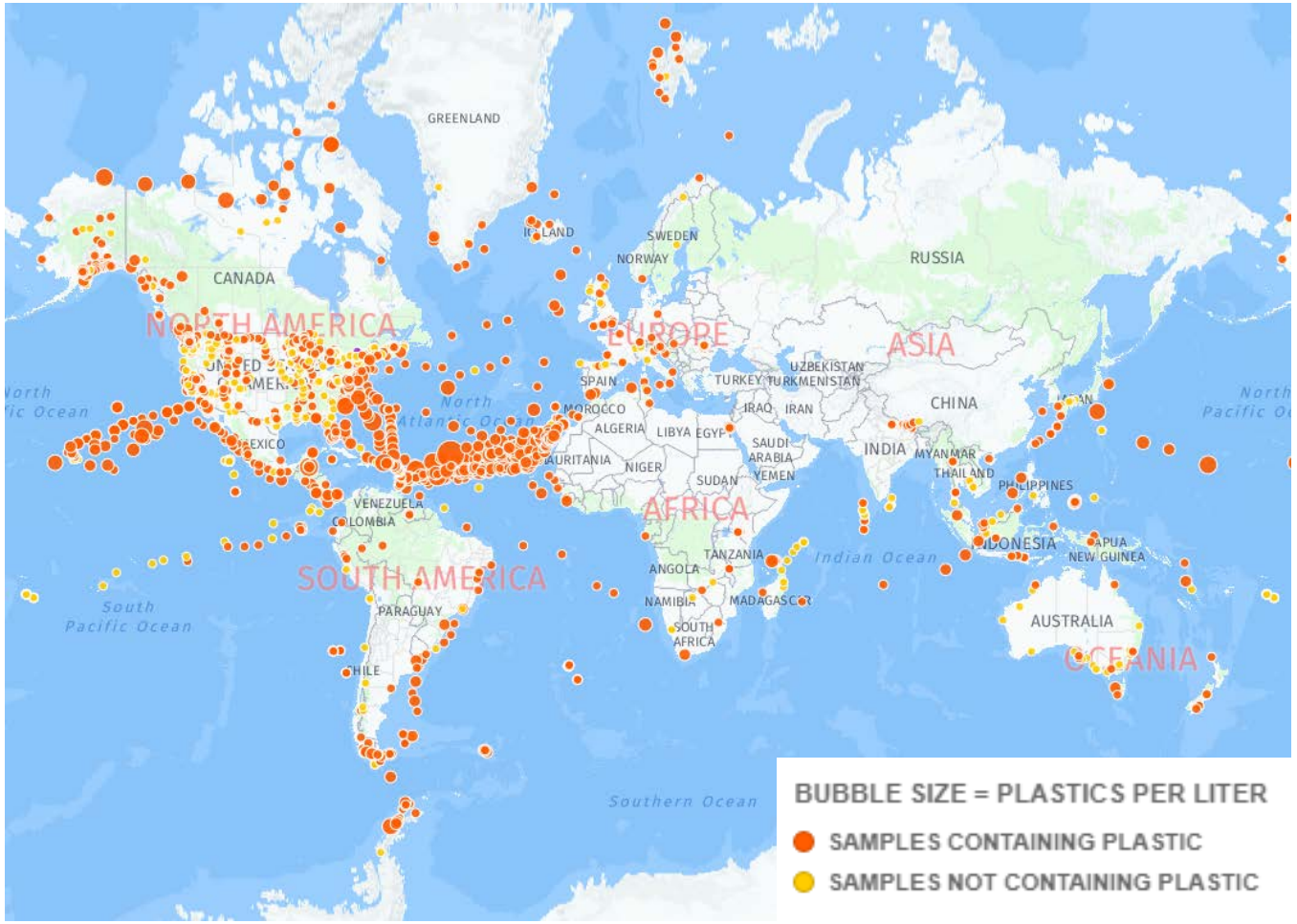
- Quantify the microfibers generated from the laundering of different fabrics.
- Understand the mechanisms that dictate the microfiber generation .
- Understand the fate of these particles in water treatment and in the environment (biodegradability).



Boucher, J., and Friot, D. (2017). Primary Microplastics in the Oceans : a Global Evaluation of Sources., IUCN, Glan, Switzerland. DOI: dx.doi.org/10.2305/IUCN.CH.2017.01.en

Microfibers Generation

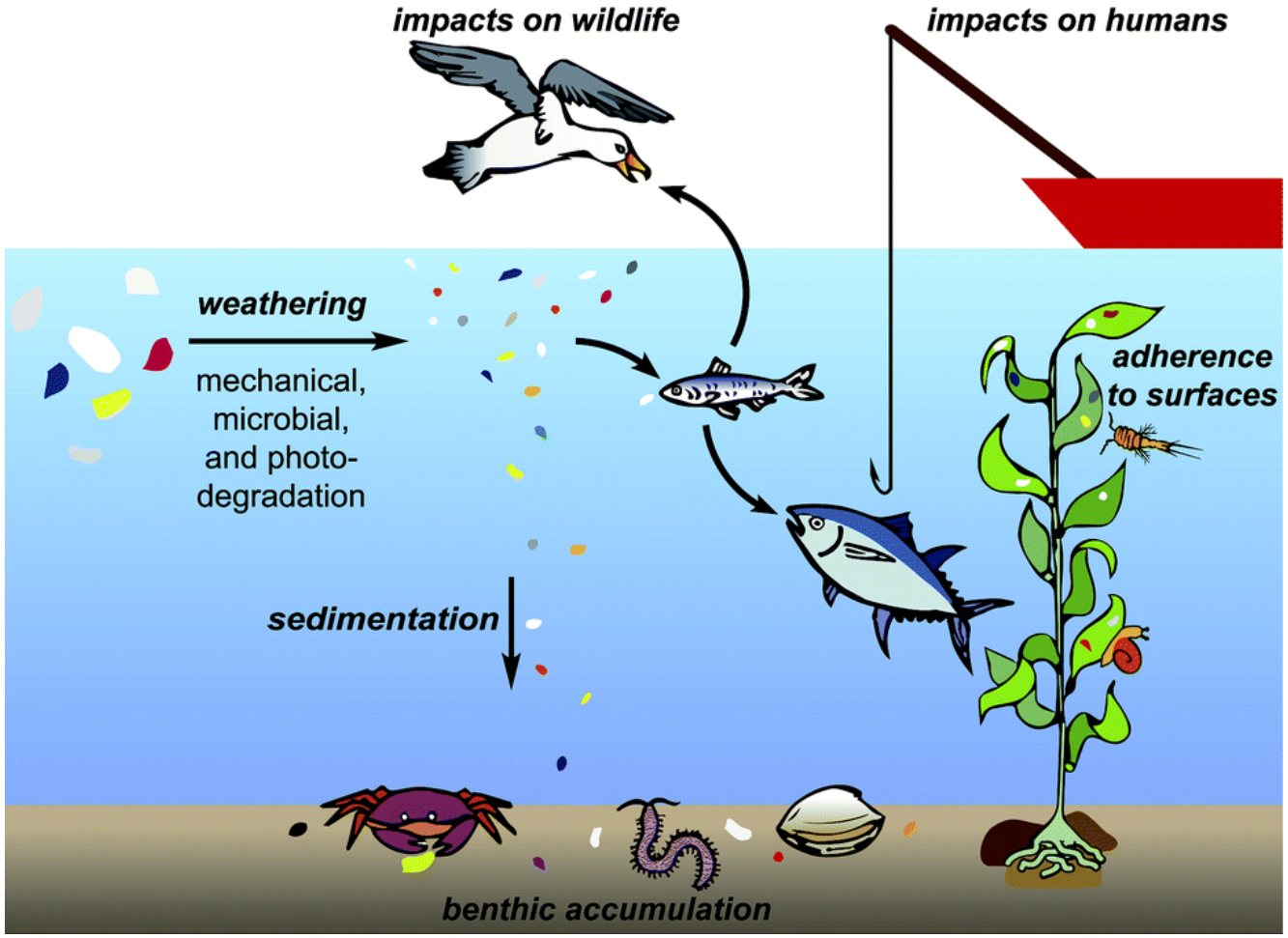
Distribution of Microplastics



http://www.adventurescientists.org/microplastics.html

Microfibers Generation

Impacts of Microplastics in the Environment

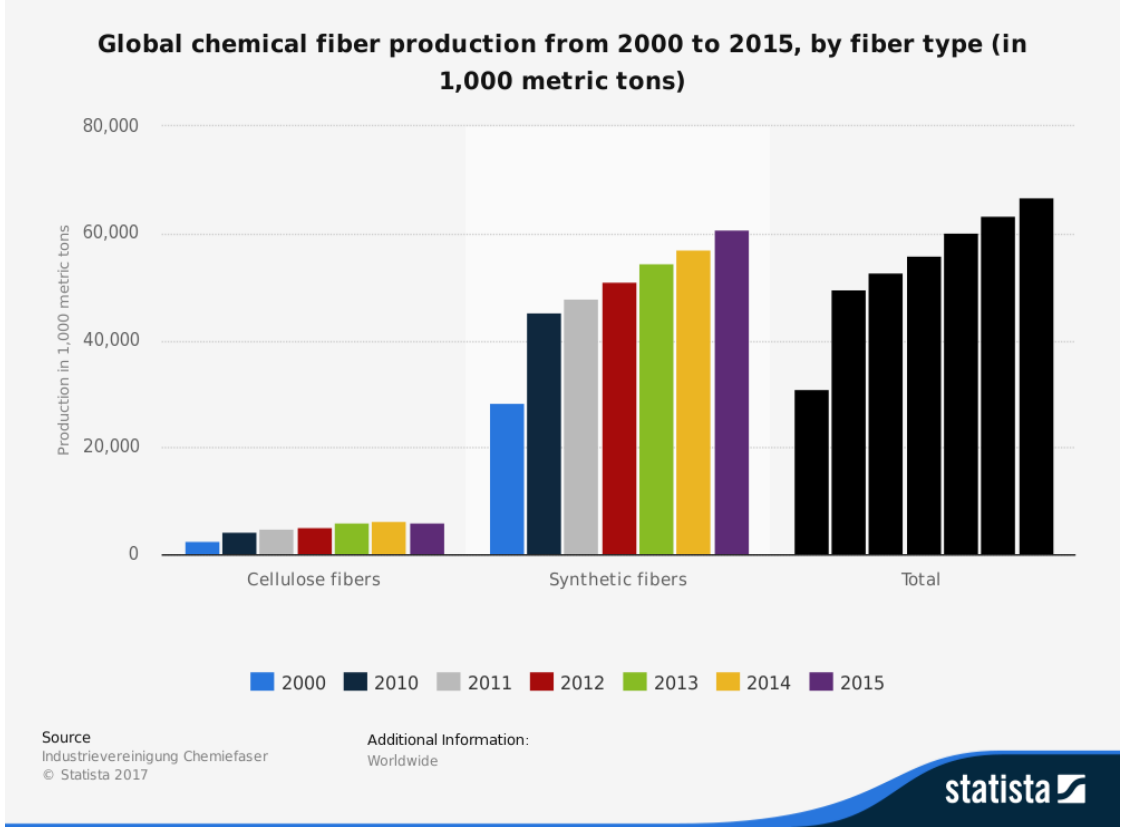


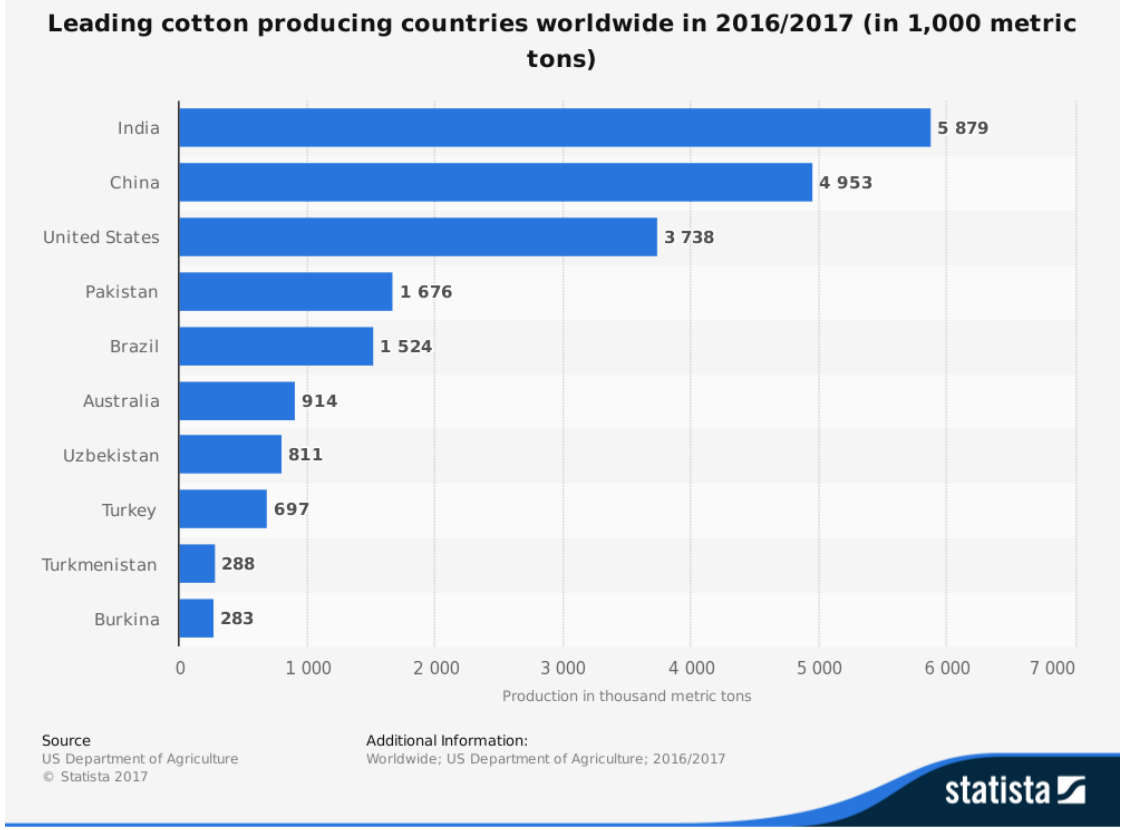
http://pubs.rsc.org/en/content/articlehtml/2016/EM/C6EM90004F

- **Weathering**
- Plastic debris are broken down into smaller particles.
- **Sedimentation**
- **Adherence to surfaces**
- **Ingestion**
- By invertebrates and fish.
- **Infiltration in the entire food web**
- By predation of these organisms, potentially affecting birds, marine mammals, and also humans.

Microfibers Generation

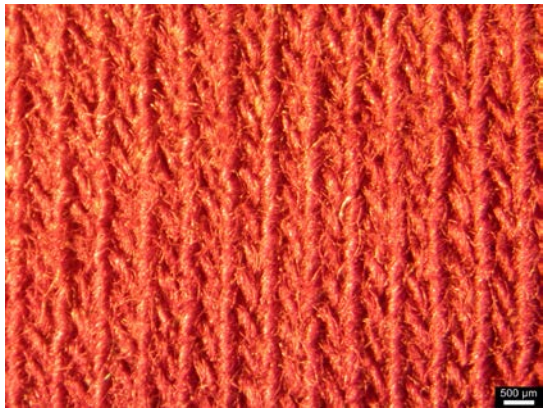
Global Chemical Fiber and Cotton Production



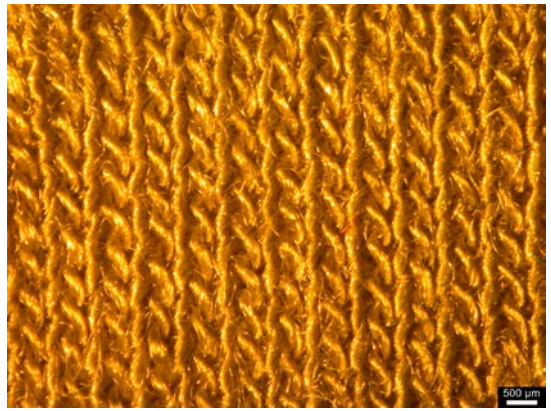


Microfibers Generation

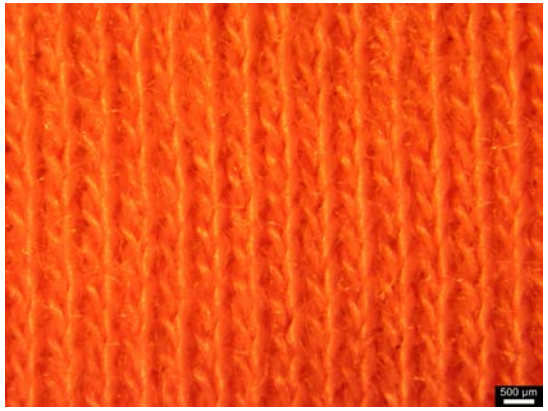
Fabric Samples



100% Cotton



100% Rayon



100% Polyester

Weft Knitted Fabric

Interlock

50/50 Polyester/Cotton

Accelerated Laundering Experiments

Experimental Flowsheet

Samples Preparation

4 in x 4 in
Pre-Cleaned

http://www.sdlatlas.com/consumable/81/Container-Seals-(pack-of-8)

Containers Preparation

- 1 piece of fabric / Container
- 25 metal balls / Container
- 150 ml Detergent Solution (1.47g AATCC Standard Liquid Detergent per 1L of DI Water) or DI water

SDL Atlas Launder-Ometer

http://www.sdlatlas.com/product/120/Launder-Ometer

Washing Cycle

16 min
At constant temperature
8 Containers / Washing Cycle

Laundering Water Collection

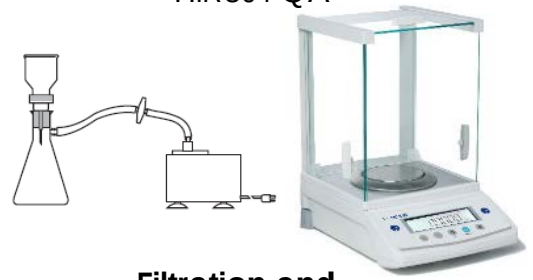
Washed Fabric

Water with Microfibers

Quantify

(Robertson et al. 1999)

Fibers Quality Analyzer
HiRes FQA

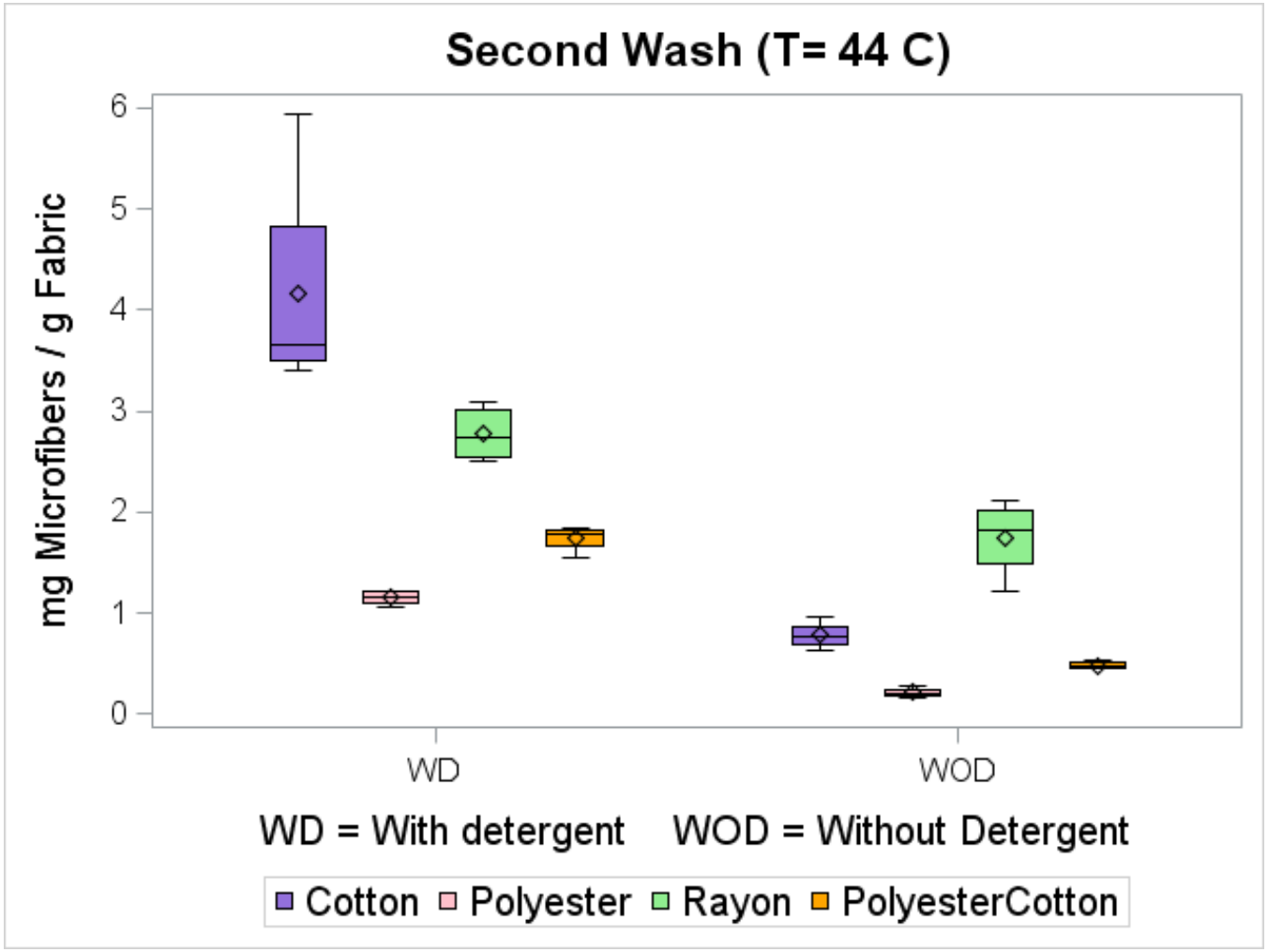


Filtration and Weighing

Robertson, G., Olson, J., Allen, P., Chan, B. E. N., and Seth, R. (1999). "Measurement of fiber length, coarseness, and shape with the fiber quality analyzer," Tappi Journal, 82(10), 93–98.

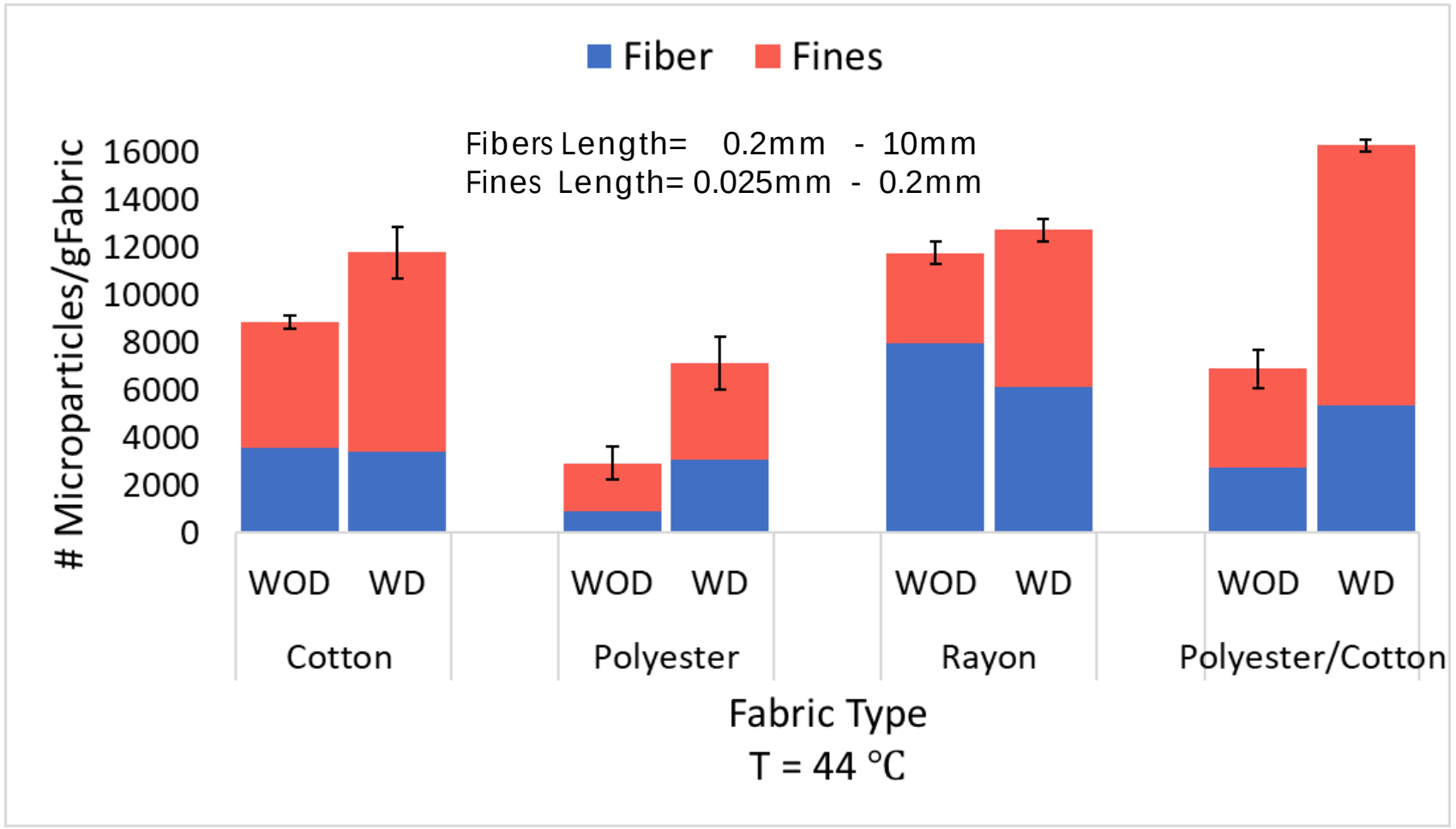
Accelerated Laundering Experiments

Results – Effect of Detergent Use



Accelerated Laundering Experiments

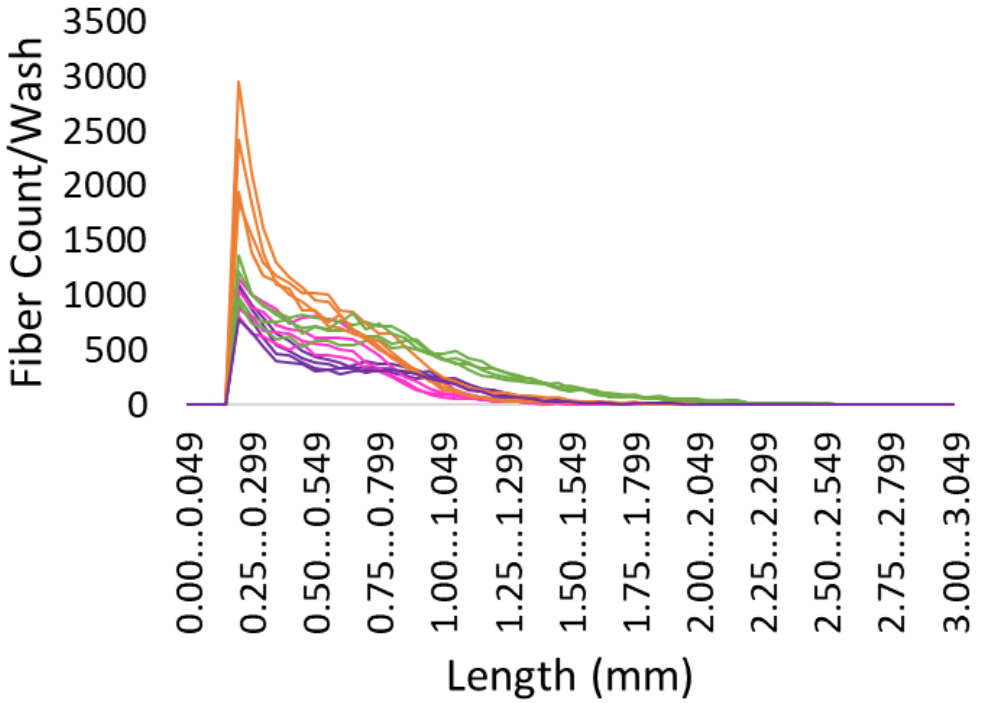
Results – Effect of Detergent Use



Accelerated Laundering Experiments

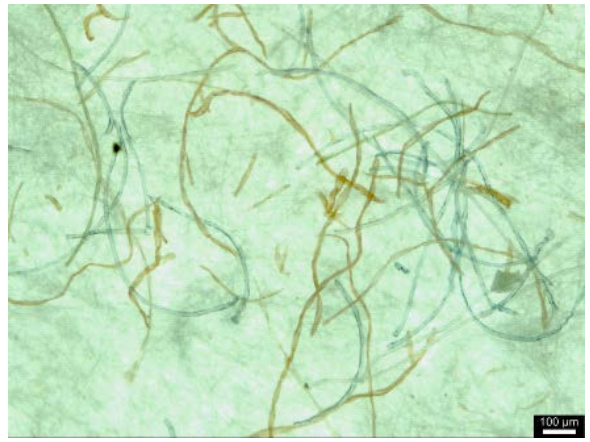
Results – Microfibers Size Distribution

Condition 2, With Detergent T = 44 °C

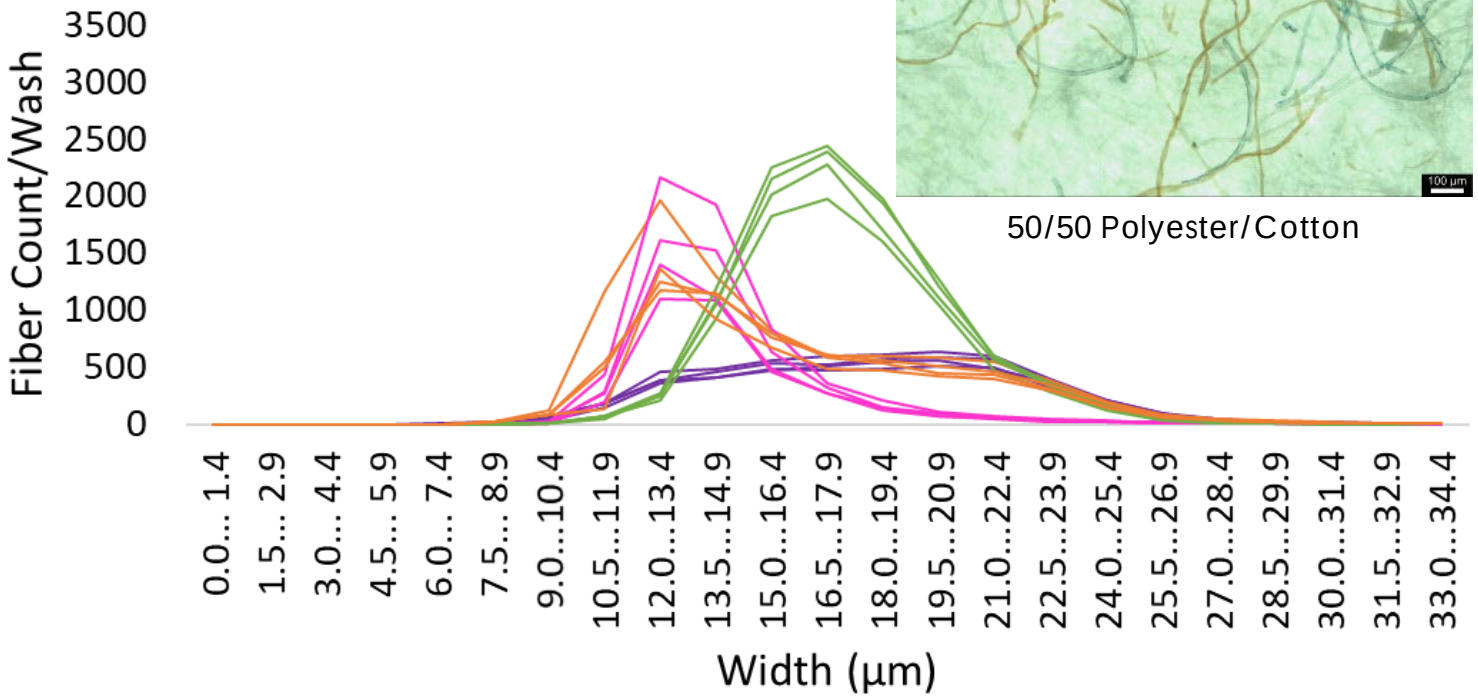


Fibers Length= 0.2mm - 10mm

Cotton = Purple
Rayon = Green
Polyester = Pink
Polyester/Cotton = Orange



50/50 Polyester/Cotton

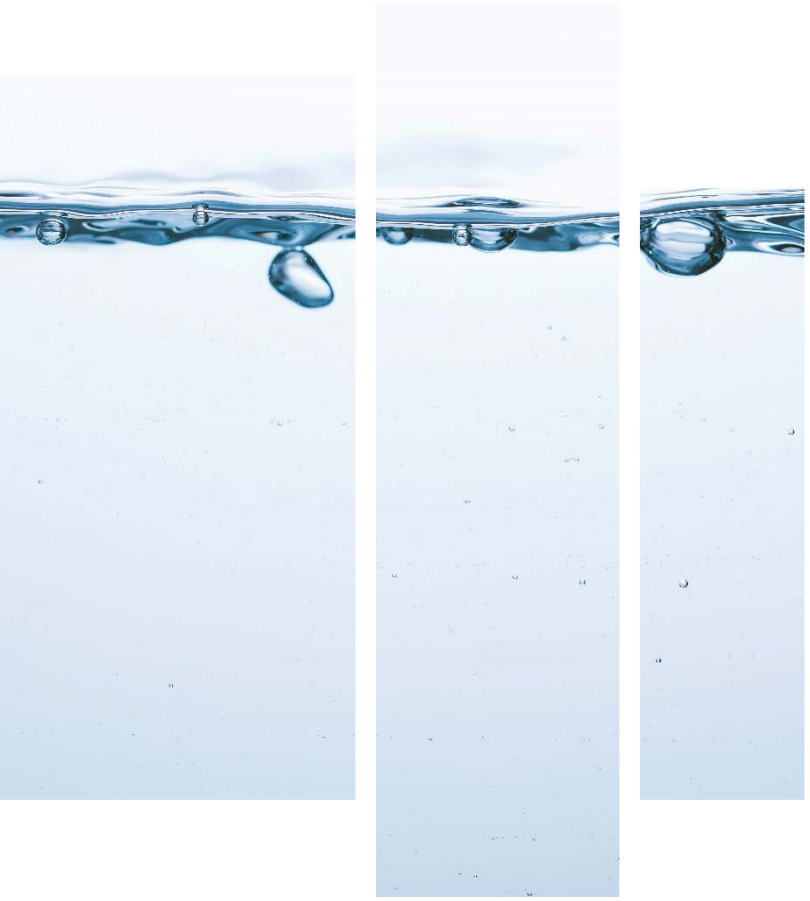


Fibers Length= 0.5mm - 10mm
Width= 7 µm - 60 µm

Accelerated Laundering Experiments

Summary

- Accelerated laundering generated 0.5 – 4.0 mg of microfibers and 5000-15000 microfibers per gram of fabric washed.
- In general, natural-based fabrics released more microfibers (2-4 mg/g fabric) during laundering than polyester (0.25-0.50 mg/g fabric).
- The detergent use causes more microfibers released from fabrics during laundering.
- The influence of temperature is not significant.
- The fiber length varies from 0.2 mm to 1.8 mm and the fiber width from 9 to 26 µm.
- More than 50% of the microfibers generated are below 200 µm in size.



Aquatic Biodegradability of Textile Yarns

Aquatic Biodegradability of Textile Yarns

Standard Method ISO 14851

Determination of the ultimate aerobic biodegradability of plastic materials in an aqueous medium - Method by measuring the oxygen demand in a closed respirometer

Purpose: assess the degree of biodegradability of plastic materials by measuring the oxygen demand in a closed container.

Unadapted Inoculum: Neuse River WWTP Activated Sludge (~ 3000 ppm of TSS).

Measurements: Biological Oxygen Demand (BOD).

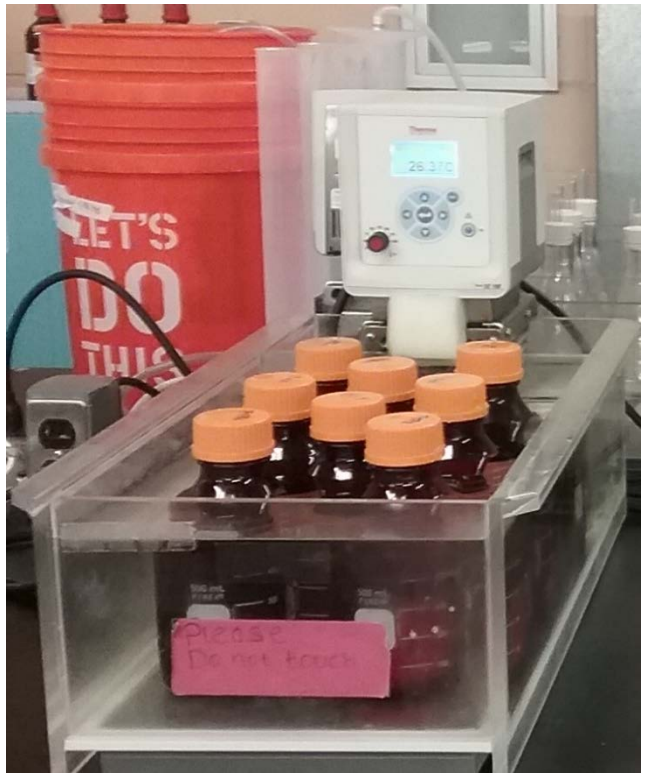
The test is valid if:

- ☑ The degree of biodegradation of the reference material is > 60%.
- ☑ The BOD of the blank (FB) does not exceed 60 mg/l, at the end of the test.

ISO 14851:1999. (2005). Determination of the ultimate aerobic biodegradability of plastic materials in an aqueous medium -- Method by measuring the oxygen demand in a closed respirometer.

Aquatic Biodegradability of Textile Yarns

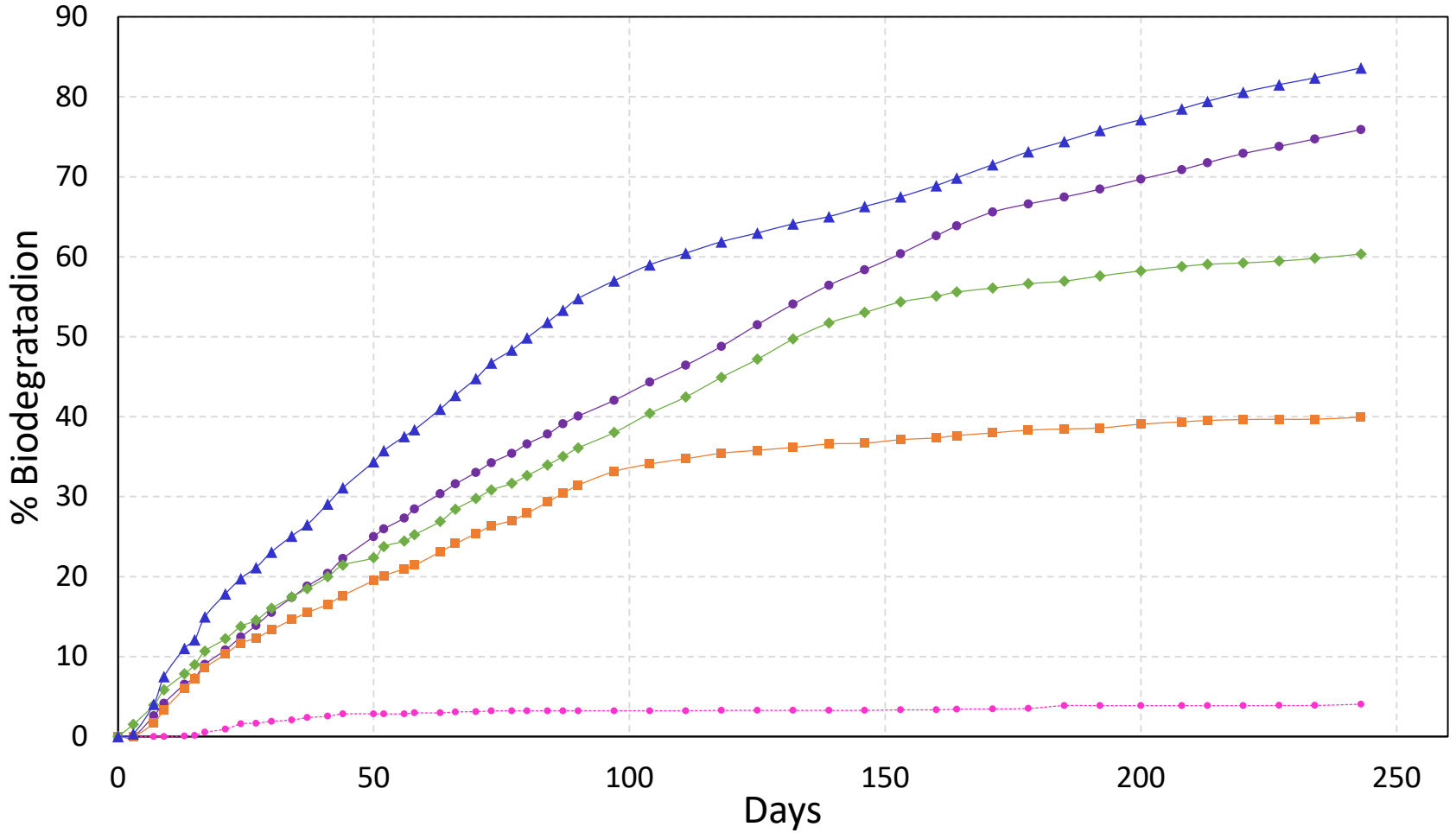
Aquatic Biodegradation System



- 1 grams Yarn per Container
- 1-2 grams of Theoretical Oxygen Demand per Container
- 4 ml of Inoculum per Container
- (~ 30 ppm)
- 3.4 mg of Oxygen per Container
- Measure Dissolved Oxygen and Re-Aerate every 2 day or as needed.

Aquatic Biodegradability of Textile Yarns

Results



Microcrystalline Cellulose
84%

Cotton
76%

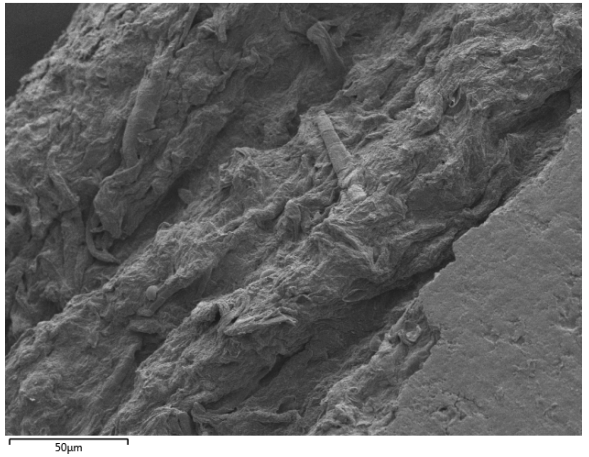
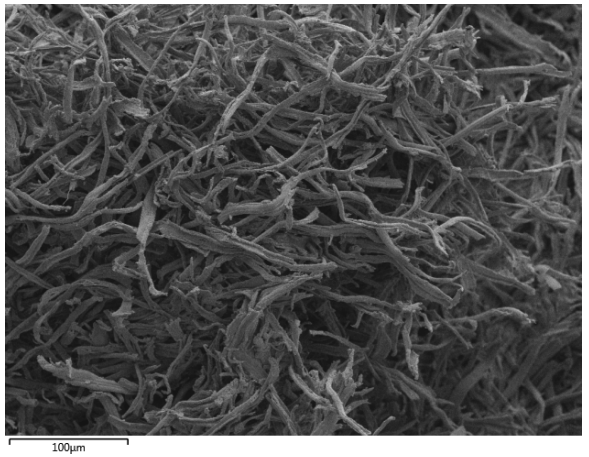
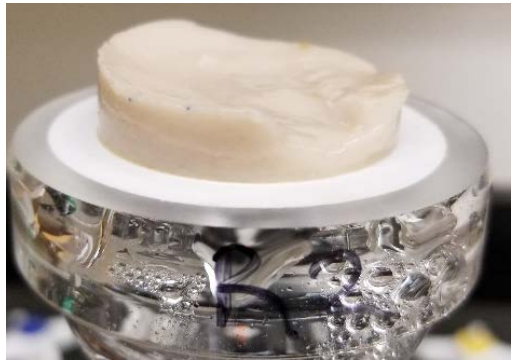
Rayon
60%

50/50 Polyester/Cotton
40%

Polyester
4%

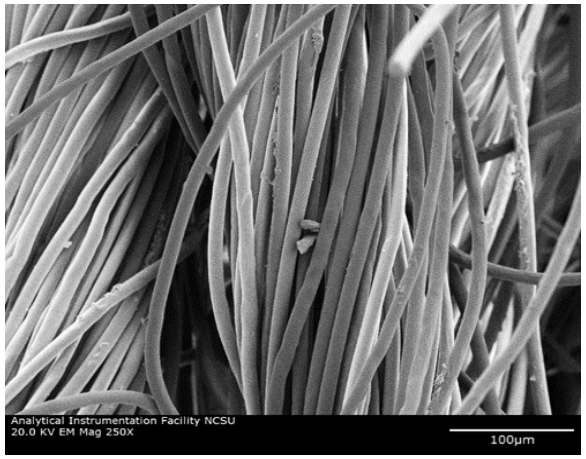
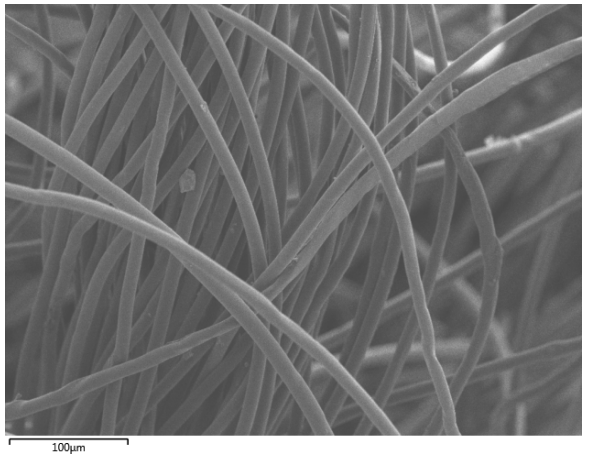
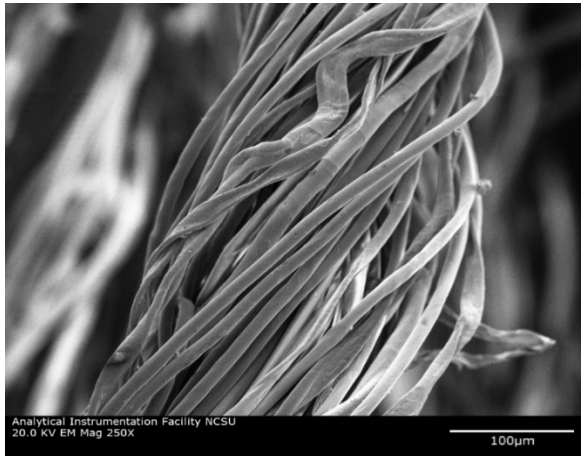
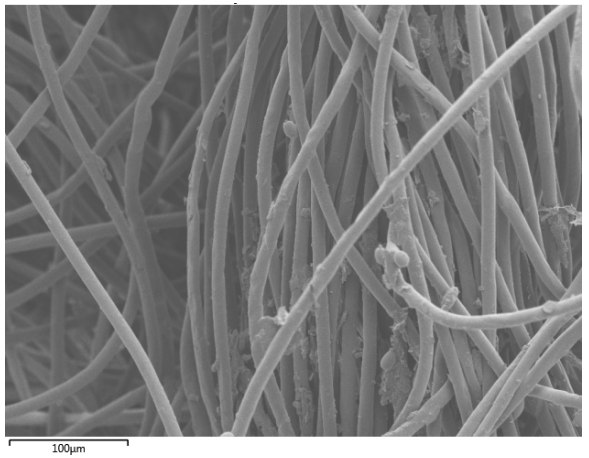
Aquatic Biodegradability of Textile Yarns

Results

	Before Biodegradation	After Biodegradation	Leftover After Biodegradation
100% Cotton Spun Yarns			
100% Rayon Spun Yarns			

Aquatic Biodegradability of Textile Yarns

Results

	Before Biodegradation	After Biodegradation	Leftover After Biodegradation
100% Polyester Spun Yarns			
50/50 Polyester/Cotton Spun Yarns			

Aquatic Biodegradability of Textile Yarns

Summary

- The **Reference Material (Microcrystalline Cellulose)** reached **84%** of degradation. This fact indicates that the inoculum worked until the end of the experiment.
- The final **BOD of the Blank** was **12 mg/l** (it did not exceed 60 mg/l).
- The final percentage of biodegradability in the materials tested was:
  - **Cotton Yarns 76%,**
  - **Rayon Yarns 60%,**
  - **50 : 50 Polyester : Cotton Yarns 40%,**
  - **Polyester Yarns 4%.**

Conclusions

- Accelerated laundering generated 0.5 – 4.0 mg of microfibers and 5000-15000 microfibers per gram of fabric.
- The generation of microfibers from laundering is affected by the use of detergent as washing agent.
- Cotton and Rayon release more microfibers than Polyester by weight and count.
- Under the testing conditions, Cotton and Rayon yarns are biodegradable, Polyester yarns are not.

Future Work

- Simulate the biodegradation process in real aquatic environments, using river, lake, or sea water using the automatic respirometer RSA PF-8000.

- Evaluate the fate of a microfiber in the wastewater plant (lab or field samples).

- Perform metagenomic studies to identify the organisms of the bacterial community in the systems under study through the analysis of the prokaryotic 16S ribosomal RNA gene (16S rRNA).

Acknowledgments

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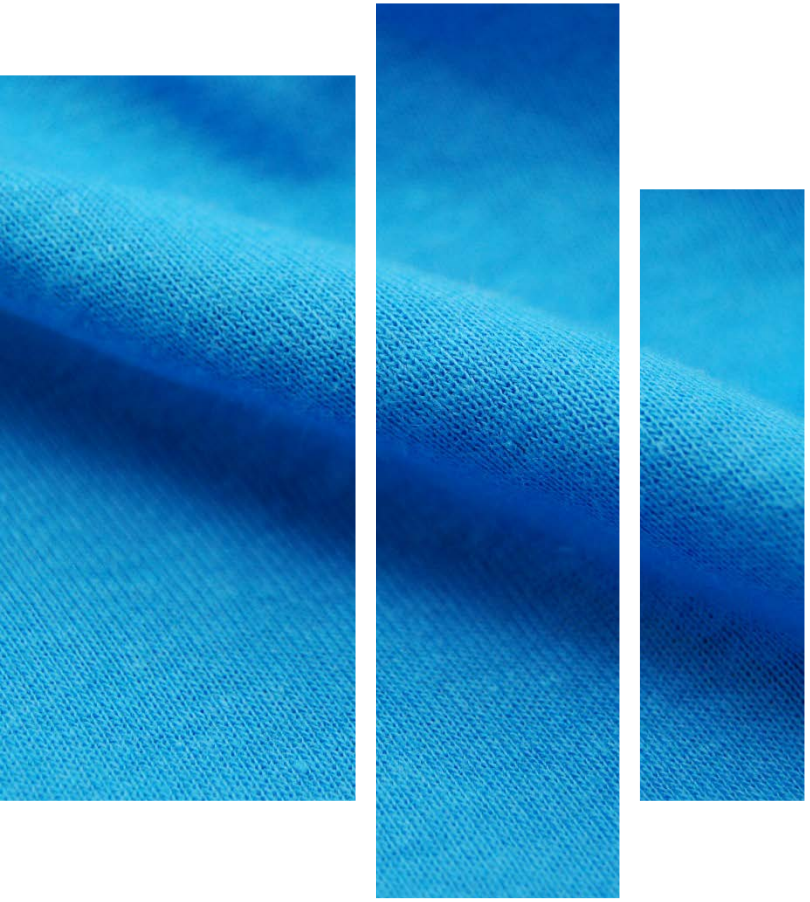
Environmental Analysis Lab

Dr. Jay Chen
Dr. Cong Tu

CITY OF RALEIGH NORTH CAROLINA

Neuse River
Wastewater Treatment Plant

Nathan Howell



Thank You

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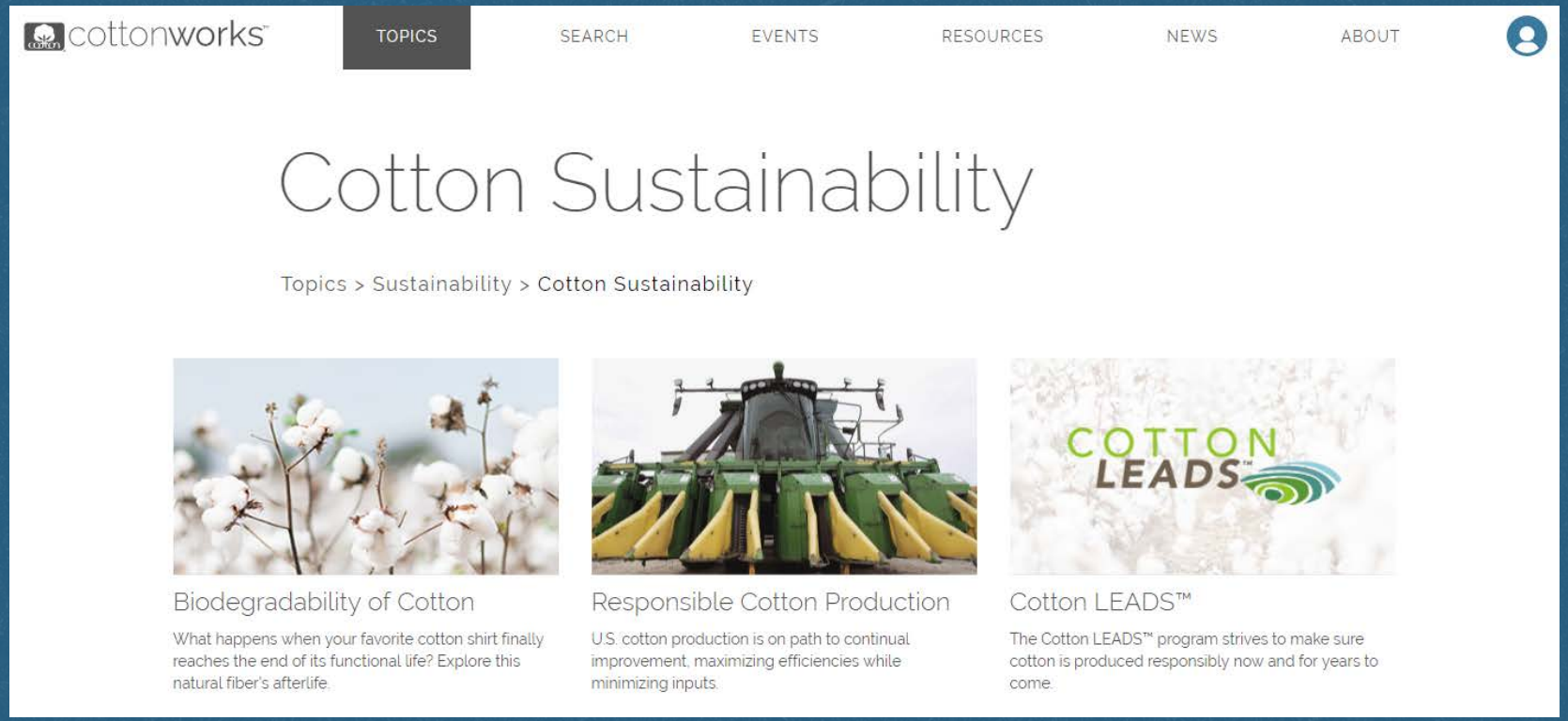

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