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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Where have they been found?

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

Ocean/River/Lake
Browne et al. (2011); Miller et al. (2017)
Baldwin et al. (2016)

Sediment
Obbard et al. (2014)

Sewage Sludge
Mahon et al. (2017)

Arctic Ice
Mahon et al. (2017)

Inside Organisms
Taylor et al. (2015)
How do they get there?

Atmosphere → WWTP → Septic System → Water Body → Soil
What can they do?

★ = pollutant e.g. pharmaceuticals, metals, etc.
What can they do?

🌟 = pollutant e.g. pharmaceuticals, metals, etc.
What can we do?

**Atmosphere**
- Better microfiber capture; Apparel/textiles with lower shedding rates

**Water Body**
- Biodegradability of microfibers; WWTP Infrastructure changes

**Soil**
- Effects?
**MICROFIBER ACTION ROADMAP**

Priority actions that key stakeholders should take over the next five years to systemically understand and address microfiber pollution, from source to sea.

<table>
<thead>
<tr>
<th>Priority Actions</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
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<tbody>
<tr>
<td><strong>LED BY ACADEMIA &amp; NGOS</strong></td>
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<td>Material Flow Analysis (MFA) and Hotspot Identification</td>
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<td>Fate and Transport Assessment</td>
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<td>Environmental Risk Assessment</td>
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<td>Establish consistent test methodologies for fiber shed rates</td>
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<td>Implement best practices shown to reduce supply chain emissions</td>
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<td>Design and invest in innovative, science-backed solutions</td>
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Learn more: [http://bit.ly/microfiberaction]  

Produced by: [Ocean Conservancy]  
[Bran School of Environmental Science & Management]  
[Future 500]
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).

Microfibers Generation

Distribution of Microplastics

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

Impacts of Microplastics in the Environment

- **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.

http://pubs.rsc.org/en/content/articlehtml/2016/EM/C6EM90004F
Microfibers Generation
Global Chemical Fiber and Cotton Production

Global chemical fiber production from 2000 to 2015, by fiber type (in 1,000 metric tons)

Leading cotton producing countries worldwide in 2016/2017 (in 1,000 metric tons)

Source: Microbildung Chemiefasern © Statista 2017
Additional Information: World wide
Microfibers Generation
Fabric Samples

100% Cotton

100% Rayon

Weft Knitted Fabric Interlock

100% Polyester

50/50 Polyester/Cotton
Accelerated Laundering Experiments

Experimental Flowsheet

Samples Preparation
- 4 in x 4 in Pre-Cleaned

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

Washing Cycle
- 16 min
- At constant temperature
- 8 Containers / Washing Cycle

Laundering Water Collection
- Washed Fabric

Water Collection
- Water with Microfibers

Quantify

Fibers Quality Analyzer
HiRes FQA

Accelerated Laundering Experiments

Results – Effect of Detergent Use

Second Wash (T = 44 C)

mg Microfibers / g Fabric

WD = With detergent  WOD = Without Detergent

Cotton  Polyester  Rayon  PolyesterCotton
Accelerated Laundering Experiments
Results – Effect of Detergent Use

Fibers Length = 0.2mm - 10mm
Fines Length = 0.025mm - 0.2mm

# Microparticles/gFabric

Cotton
Polyester
Rayon
Polyester/Cotton

Fabric Type
T = 44 °C
Accelerated Laundering Experiments

Results – Microfibers Size Distribution

Condition 2, With Detergent T = 44 °C

Fibers Length= 0.2mm - 10mm
Width= 7 µm - 60 µm

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

50/50 Polyester/Cotton
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.

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

<table>
<thead>
<tr>
<th>Material</th>
<th>Biodegradation %</th>
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<tbody>
<tr>
<td>Cotton</td>
<td>76%</td>
</tr>
<tr>
<td>Rayon</td>
<td>60%</td>
</tr>
<tr>
<td>50/50 Polyester/Cotton</td>
<td>40%</td>
</tr>
<tr>
<td>Microcrystalline Cellulose</td>
<td>84%</td>
</tr>
<tr>
<td>Polyester</td>
<td>4%</td>
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</tbody>
</table>

Days vs % Biodegradation
Aquatic Biodegradability of Textile Yams

Results

100% Cotton Spun Yarns

Before Biodegradation

After Biodegradation

Leftover After Biodegradation

100% Rayon Spun Yarns

Before Biodegradation

After Biodegradation
Aquatic Biodegradability of Textile Yarns

Results

Before Biodegradation

100% Polyester Spun Yarns

50/50 Polyester/Cotton Spun Yarns

After Biodegradation

Leftover After Biodegradation
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 Yams 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 yams are biodegradable, Polyester yams 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).
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Thank You

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Breaking it Down:
Cotton’s Biodegradability in Aquatic Environments
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