Recycled Cotton Fibres in Technical and Clothing Applications

Pirjo Heikkilä¹, Taina Kamppuri¹, Eetta Saarimäki¹, Jukka Pesola², Noora Alhainen², Petri Jetsu¹

¹ VTT Technical Research Centre of Finland
² Pure Waste Textiles, Helsinki, Finland
Contents

- Motivation
- Recycling methods for textile materials
- Cotton recycling examples
  - Mechanical recycling to nonwovens
  - Mechanical recycling to yarns with open-end and ring spinning
  - Chemical recycling
- Summary and conclusions
- Future prospects and further work
Motivation

- It is difficult to answer increased fibre demand sustainably with current fibre base.

Amount of textile and clothing waste is huge, in Finland 13 kg/person/year.

- EC decision: separate textile waste collecting to be started in Europe, needs to utilized as well.

2025
Recycling methods

# Different textile fractions

<table>
<thead>
<tr>
<th>Type</th>
<th>Pre-consumer</th>
<th>Post-consumer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin</td>
<td>Industry</td>
<td>Users</td>
</tr>
<tr>
<td>Composition</td>
<td>Known</td>
<td>Un-known</td>
</tr>
<tr>
<td>Cleanliness</td>
<td>Clean</td>
<td>Un-known</td>
</tr>
<tr>
<td>Quality</td>
<td>Good</td>
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Different textile fractions

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</tbody>
</table>

Un-known
Materials and Methods

Pre-consumer cotton
- Industrial cutting waste

Post-consumer cotton
- Sorted and opened
- Dust-like opening side-stream
- Sorted and grinded

Mechanical recycling
- Nonwovens / foam laying
- Yarns / open-end spinning
- Yarns / ring-spinning

Chemical recycling
- Fibres / cellulose carbamate technology and wet-spinning
Foam laying - Method

- Like wet-laying, but aqueous foam instead of water as transport media → less water & less drying
- Typical process
  1. Surfactants and water mixed into foam
  2. Fibres added
  3. Foam transferred onto wire for removal of water
Foam laying - Pilot scale
Dust-like recycled post-consumer cotton mixed with pulp

Cotton content from 10 % to 70 %
Targeted weight 100 g/m²

Heikkilä P. et al., Telaketju - Towards Circularity of Textiles, VTT Research Report, VTT-R-00062-19,
Foam laying - Lab scale
Pre-consumer cotton mixed with other fibres

Mixtures of following fibres:
• Cellulose pulp
• Bi-component binder fibres
• Lyocell

<table>
<thead>
<tr>
<th>No</th>
<th>Fibres</th>
<th>Weight (g/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>r-CO 70% / pulp 30%</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>r-CO 90% / bico 10%</td>
<td>70</td>
</tr>
<tr>
<td>3</td>
<td>r-CO 45% / lyocell 45% / bico 10%</td>
<td>70</td>
</tr>
</tbody>
</table>

NordicBio project – unreported data
Ring spinning - Lab scale
Post-consumer cotton mixed with virgin and recycled fibres

Cotton opened 5 or 6 times, mixed with virgin cotton & viscose, and post-consumer r-PET

<table>
<thead>
<tr>
<th>Fibre composition</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 % r-CO</td>
<td>Sliver was formed, but spinning required blending (with used machine)</td>
</tr>
<tr>
<td>50 % r-CO (6) / 50 % CO</td>
<td>A yarn was difficult to spin, resulted only small and weak samples</td>
</tr>
<tr>
<td>50 % r-CO (6) / 50 % CV</td>
<td>Spinning worked well and resulted yarn (88 tex and 650 twists/meter) – see next slide</td>
</tr>
<tr>
<td></td>
<td>The yarn was test knitted, but it was too thick for a lab scale knitting machine</td>
</tr>
<tr>
<td>30 % r-CO (5) / 70 % CV</td>
<td>Spinning worked well and resulted yarn (66 tex, 650 twists/meter)</td>
</tr>
<tr>
<td></td>
<td>The yarn suited well for knitting – see next slide</td>
</tr>
<tr>
<td>40 % r-CO (5) / 40 % r-PET / 20 % CV</td>
<td>Roving was formed, but it was uneven and yarn spinning was not possible</td>
</tr>
</tbody>
</table>

Ring spinning - Lab scale
Post-consumer cotton mixed with virgin and recycled fibres

50 % r-CO (6) / 50 % virgin CV
Yarn

30 % r-CO (5) / 70% virgin CV
Yarn and knitted material

Heikkilä P. et al., Telaketju - Towards Circularity of Textiles, VTT Research Report, VTT-R-00062-19,
Ring spinning - Pilot & industrial scale
Mixture of chemically and mechanically recycled cotton

Chemically recycled cotton via cellulose carbamate technology in pilot scale

Mixed 1:1 ratio with pre-consumer cotton for ring spinning and knitting in industrial scale

Designer dress by Anna Ruohonen

<table>
<thead>
<tr>
<th>Yarn</th>
<th>Fabric grammage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>Tensile strength</td>
</tr>
<tr>
<td>39 tex</td>
<td>3 N</td>
</tr>
</tbody>
</table>

Open-end spinning - Industrial scale
Mixture of post- & pre-consumer cotton and r-PET

Post-consumer cotton (20 %), pre-consumer cotton (40 %) and recycled polyester from bottles, r-PET (40 %)

Yarn and fabric quality did not deviate from typical commercial OE yarns

- Yarn count 20.3 Ne (30 tex), 15.4 twists per inch and yarn Lea strength was 66.57 lbs
- Knitted fabric shrinkage 2.8 % and 2.3 % (length and width), and spirality of 0.5% after one wash

➢ Material ready for commercialization

Pure Waste Textiles, unreported data
Separate collection of textile waste to be started in EU member states by 2025 – we can expect to have recycling targets e.g. for 2030

We have demonstrated recycling of various types of both pre- and post-consumer cotton using processes from lab to pilot and industrial scale

Recycled cotton can be used for making nonwovens and yarns – application possibilities vary from technical to clothing & fashion

Mechanical recycling processing – shedding and opening – reduce fibre length while chemical recycling restores it

Depending on fibre and its quality there are different processes to be selected in order to get desired material properties and, thus, enabling using recycled cotton in high-value products
## Future Prospects

- Knowing quality is essential in selecting best technology for obtaining highest value
  - Standardization needed

- Sorting process is essential for mixed post-consumer materials, but not needed for known batches e.g. industrial side streams
  - Keeping different textile waste fractions separate, if that affects their suitability for recycled products

- Hygiene might be an issue from textile waste coming from consumers
  - Cleaning process to enable post-consumer from private consumers to be used e.g. in skin contact, personal care and hospital applications
Further Work

Telaketju 2 BF project
National Finnish action building circular textile ecosystem from collection & sorting to recycling as well as new circular business models.
Coordinated by VTT, 3 research partners, 5 company projects including Pure Waste Textiles, over 20 companies co-funding the project with Business Finland.

www.telaketju.fi

NordicBio project
Swedish-Finnish action aiming for the development of new solutions for replacing synthetic disposable products with bio- and circular economy materials in hospital textile applications.
VTT develops cleaning process and foam laid materials.
Pure Waste develops yarns & fabrics
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Acknowledgements

VTT personnel in lab and pilots

All our project partners

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• Telaketju Tekes -project, 2017-2019
• NordicBio -project, 2018-2020
• Telaketju 2 BF -project, 2019-2021

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beyond
the obvious