Report over contents of textile waste fraction

Customer:	Delivery:	Date of finished processing:	Date of publishing:
xxx	**12930 kg**	xx-xx-xxxx	xxxxx

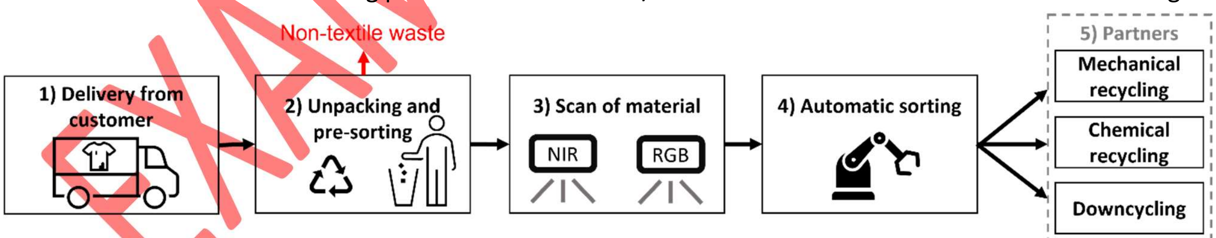
Introduction

The purpose of this report is to document the contents in a textile waste fraction, delivered at NewRetex A/S. The results are collected internally at NewRetex A/S, who have also been responsible for analysing and documenting them. The contents of this report are divided in the following sections:

1. **Methods:** Explains how the material is processed at NewRetex A/S and how data has been collected and analysed.
2. **Recycling options for different material fractions:** Outlines the general possibilities of recycling, based on the 10 material fractions, currently sorted at NewRetex A/S.
3. **Content and recyclability in the delivered material:** The collected data is presented, and it is estimated how much of the material that can be recycled and how.
4. **Discussion:** The results are discussed, and potential recommendations are presented for improved collection/handling/delivery of the material.
5. **Environmental impacts:** The main concerns regarding the environmental impacts of fibre and yarn manufacturing are outlined for virgin materials, and it is discussed how recycled materials can help reduce these impacts. Furthermore, estimate calculations of the environmental impacts of exemplary yarns are given for both virgin and recycled materials.
6. **Authors:** Information on the authors of the report.
7. **Appendix:** Image documentation to support the points presented in the discussion is found here.

1. Methods

A schematic of the overall sorting process at NewRetex A/S is seen below and elaborated in the following:



1. The material is received from the customer and put into inbound storage.
2. Bags and boxes are opened, and everything that is not recyclable textiles is removed, sorted and weighed. The fraction of not recyclable textiles is divided into four types:
    a. Footwear including shoes, boots, etc. cannot currently be recycled.
    b. Wet/mouldy/dirty textiles are not fit for recycling as the material is not washed.
    c. Multi-layer textiles cover, among others, jackets, duvets, pillows, etc. Our NIR-sensor can only "see" the surface of the textiles. Thus, we cannot currently detect the material within the multi-layer textiles, so they are not sorted for recycling.

   d. Other waste covers different material fractions such as plastic packaging, cardboard boxes and wrongly sorted waste items. This waste is sorted further into waste fractions and treated by relevant waste processing companies.

3. The pre-sorted textile waste is passed under our NIR sensor, which uses artificial intelligence algorithms to identify the material composition. Furthermore, the colours of the textiles are determined. We can detect over 30 different material compositions and any colour, or combination of colours. Every scan is saved in our database and is used to track the textiles.
4. Currently, our robots sort the textiles into one out of 10 defined fractions. The content of each fraction is weighed hereafter. Our fractions can be redefined into any mixture of the materials and colours, that we can detect.
5. Every sorted material fraction is sent to recycling or downcycling at one of our partners, depending on the material composition and quality. We differentiate between three types of recycling:
   a. Mechanical fibre-to-fibre recycling is conducted in Turkey, Italy, Spain, Portugal, Finland, Holland, and Germany. The recycling is done through at carting process, which uses needle-rolls to “open” the fibres of the material. This provides a pulp similar to virgin cotton, but with reduced fibre length, due to wear and tear. Thus, the mechanically recycled material must be mixed with virgin fibres or chemically recycled fibres to create a high quality yarn. Typically, between 20% and 70% of mechanically recycled fibres are used depending on the original quality of the textiles.
   b. Chemical fibre-to-fibre recycling is done in Sweden, Finland, and Austria. The processes are more resource intensive than mechanical recycling. On the other hand, the fibers are fully regenerated in chemical recycling. Thus, chemically recycled fibers do not need to be mixed with virgin material before spinning. Thus, this recycling type is well suited for low-quality waste textiles.
   c. Downcycling is done in Denmark and in many of the countries working with mechanical recycling. An example of downcycling is in high quality composite office desks, made in Denmark. Another example is non-woven products used insulation in for example in the car industry or acoustic panels.

2. Recycling options for different material fractions

In Table 1 below, an overview is provided of the typical options for recycling, based on the material type.

Material fraction	Mechanical fibre-to-fibre recycling	Chemical fibre-to-fibre recycling	Downcycling
Cellulose mix (viscose, Lyocell, bamboo, etc.)	X	X	
Pure cotton	X	X	
Cotton/elastane + Cotton/pan (acrylic)		X	X
Cotton/polyester, over 60% cotton	X	X	
Cotton/polyester, under 60% cotton	X	X	X
Pure polyester	X	X	
PA (nylon) mix		X	X
Silk mix + wool mix	X		x

Table 1: *Overview of the most common recycling methods for the different material fractions.*

The recycling possibilities above depend mainly on the material types within the textile, but also on fabric type (knit, weave, yarn type), the presence of accessories (buttons, zippers, etc.), and how worn out the textile is. Thus, the recyclability does not only depend on the material type, which is also the reason that the same material fractions are processed in several ways, as seen in Tables 1 and 2. When choosing the recycling partner to process a batch of waste textiles, mechanical fiber-to-fiber recycling is prioritized highest, followed by chemical recycling. Only if fiber-to-fiber recycling is not possible, downcycling is chosen.

In Tables 1 and 2, the term *"mix"* denotes a category which can also contain other material fractions than the ones directly denoted in the category name. An example is the *"Silk mix + wool mix"* fraction. This will contain pure wool and pure silk but also mixes of wool and acrylic. In this way, over 95% of the textiles that we receive, are sorted into one of the 10 fractions. The pure fractions are denoted: "pure" and have a purity of 95%-99% fibre weight.

3. Contents and recyclability in the delivered material

Table 2 below, shows collected data on the delivered material contents. Note that measurement uncertainties are present. Furthermore, please note that the percentages for recycling are based on the best current estimations and denote the amount of material sent for a specific recycling method. However, **mechanical recycling has a material loss of about 20%, and other recycling methods have losses as well.** New technologies are in constant development and the possibilities for recycling are improving day-by-day. Thus, **the percentages of recycled material will increase in the future**.

Material fraction	Amount [kg]	Amount [%]	Mehcanical fiber-to-fiber recycling	Chemical fiber-to-fiber recycling	Downcycling	Other waste treatment
Cellulose mix	210	1,62%	100%	0%	0%	0%
Cotton 100%, mixed colors	1.562	12,08%	80%	20%	0%	0%
Cotton 100%, white and grey	831	6,43%	100%	0%	0%	0%
Cotton 100%, dark	304	2,35%	100%	0%	0%	0%
Cotton/elastane + Cotton/pan	2.234	17,28%	0%	0%	100%	0%
Cotton/polyester, over 60% cotton	2.427	18,77%	90%	0%	10%	0%
Cotton/polyester, under 60% cotton	50	0,39%	60%	0%	40%	0%
Pure polyester	3.023	23,38%	100%	0%	0%	0%
PA mix	135	1,04%	0%	30%	70%	0%
Silk mix + wool mix	789	6,10%	100%	0%	0%	0%
Recyclable textiles in total	**11.565**	**89,44%**	**8.621 kg**	**352,9 kg**	**2.591 kg**	**0 kg**
Footwear	102	0,79%	0	0	0	100%
Wet/dirty/mouldy textiles	35	0,27%	0	0	0	100%
Multi-layer textiles	165	1,28%	0	0	0	100%
Other waste fractions	1.063	8,22%	0	0	0	100%
Not recyclable textiles in total	**1.365**	**10,56%**	**0 kg**	**0 kg**	**0 kg**	**1.365 kg**
Indleveret materiale i alt	**12.930**		**8.621 kg**	**352,9 kg**	**2.591 kg**	**1.365 kg**

Table 2: *Overview of the composition in the delivered material, and the potential recycling methods.*

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4. Discussion

Based on the data, presented above, the following conclusions can be made for the delivered material:

- **11.565 kg** are fit for recycling or downcycling. This amounts to **approx. 89,4%** of the delivered material.
    - **8.621 kg** can be recycled mechanically. This amounts to **approx. 66,7%** of the delivered material.
    - **352,9 kg** can be recycled chemically. This amounts to **approx. 2,73%** of the delivered material.
    - **2.591 kg** can be downcycled to other products, which amounts to **approx. 20,0%** of the delivered material.
- The delivered material contained **1.365 kg** of other waste fractions. This amounts to **approx. 10,6%** of the delivered material. This material will be sorted out into the relevant waste fractions and be treated as waste, where some of the fractions such as the plastic packaging will be sent for recycling.

The delivered material is generally in a very good condition, delivered on pallets. The largest part of the non-recyclable textile fraction were plastic packaging which was sent for recycling. We encourage to keep collecting, treating and delivering the material in this manner.

Environmental impacts

While the fashion industry is held accountable for up towards 10% of the global CO2-ekvivalent emissions[1], more than 80% of these are attributed to the production from the raw materials to piece goods[2]. Some of these emissions stem from the extraction of raw material (from plants/animals or crude oil) and transport of fibres and piece goods between steps in the value chain. Furthermore, wet treatments such as dyeing make up a substantial part of the energy usage when producing textiles, attributing to the large number of emissions[3]. A large portion of these emissions can be avoided through recycling by reducing the need for (virgin) raw materials, creating more local supply chains and avoiding wet treatments through efficient colour sorting.

Furthermore, the textile industry is responsible for 4% of the global consumption of fresh water, which is particularly caused by the cultivation of cotton crops, which uses approx. 10.000 L fresh water per kg. cotton[4]. This can cause large problems in areas which are vulnerable to drought, as was the case of the Aral Sea in Uzbekistan which was the world's 4th largest lake in 1960. By 2007 the lake had reduced to only 10% of its size, as a result of 40 years of water diversion for irrigation of mainly cotton crops in the surrounding districts. The great drought has brought a massive downfall in the fishing industry of surrounding local communities, removing the livelihoods of up to 4.4 million people.

[1] European Parliament. The impact of textile production and waste on the environment (infographic). (2022). 20201208STO93327
[2] Roos, Sandra & Sandin, Gustav & Peters, Greg & Spak, Björn & Bour, Lisa & Perzon, Erik & Jönsson, Christina. White paper on textile recycling. (2019). 10.13140/RG.2.2.31018.77766.
[3] Hasanbeigi, Ali & Price, Lynn. A review of energy use and energy efficiency technologies for the textile industry. Renewable and Sustainable Energy Reviews. (2012). 16. 3648–3665. 10.1016/j.rser.2012.03.029.
[4] Ellen MacArthur Foundation, A new textiles economy: Redesigning fashion's future, (2017, http://www.ellenmacarthurfoundation.org/publications).

While the remaining water in the Aral Sea contains high concentrations of toxic chemicals, the receded sea has also left huge salty desert planes from which toxic dust would be spread by wind to surrounding regions. This has led to the surrounding regions having high rates of cancer, respiratory illnesses and much higher mortality rates compared to the global average. [5]

Natural fibres can have issues with the spread of nutrients such as nitrogen and phosphorus from fertilizer, causing local bodies of water to be filled with phytoplankton which can result in oxygen depletion, also referred to as eutrophication[6]. Furthermore, the natural fibers can also cause contamination of local ecosystems with toxic chemicals from pesticides or insecticides, as was also the case for the Aral Sea. This is especially an issue for cotton cultivation, which consumes 24% of the global market for insecticides and 11% for pesticides[7]. By recycling old fibres, the need for producing new fibres is reduced, thereby reducing the environmental impacts from cultivation. It is noted that ecological cotton has significantly lower impacts than conventional cotton, in terms of chemical use, eutrophication and fresh water usage.

The synthetic fibres do not cause the same issues related to cultivation, as they are instead mostly based on fossil sources (crude oil). By recycling synthetic fibres, we can reduce the consumption of fossil fuels and move towards a fossil-free future. For synthetic fibres, large environmental impacts are also present in relation to the colouring and other wet treatments.

The various environmental impacts, explained above, can be quantifies through the Material Sustainability Index (MSI) by HIGG[8]. MSI contains 5 different indices, which each describe different environmental impacts per kg. fiber, yarn or textile material. In this case, numbers are estimated for piece goods;

- **Global warming** $[\mathrm{CO_2} - \mathrm{eq}]$; measure of the emitted green house gasses.
- **Eutrophication** $[\mathrm{kg\ PO_4} - \mathrm{eq}]$; measure of the local spread of nutrients such as phosphorous.
- **Water usage** $[\mathrm{m}^3]$; measure of freshwater consumption.
- **Depletion of fossil fuels** [MJ]; measure of consumption of fossil fuels.
- **Chemistry** [USEtox comparative toxic units]; measure of the usage of toxic chemicals.

For a given fiber material, yarn type, or fabric type, the corresponding MSI indices can be estimated, assuming that sufficient data is available. However, many factors influence the accuracy of the numbers, such as: material types, production methods, production countries, transportation, amount of sustainable energy in energy mix of production countries, fabric type, recycling methods, colour composition, wet treatment types and methods, etc. This brings an inherent uncertainty when using standardized average values, such as the MSI values. However, to indicate the environmental impacts and potential improvements from recycling, some examples have been extracted from the HIGG MSI as seen in **Table 3.** The estimations take offset in a knitted piece good of a ring-spun Ne30/1 yarn, which is often used in t-shirts. Heat-setting has been included in all cases, and for the cases with dyeing, scouring is also included.

The recycled materials in **Table 3** represent yarns of 100% mechanically recycled fibres. Such yarns are not currently feasible to produce, as the fiber quality is too poor for a Ne30/1 yarn. Instead, 80%-50% virgin material is often mixed with the recycled fibres prior to spinning. If recycled fibres are mixed with 50% virgin fibres, it would roughly correspond to **dividing the difference in environmental impacts** of virgin and

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[5] Hoskins, Tansy. Cotton production linked to images of the dried up Aral Sea basin. (2014, https://www.theguardian.com/sustainable-business/sustainable-fashion-blog/2014/oct/01/cotton-production-linked-to-images-of-the-dried-up-aral-sea-basin)
[6] National Ocean Service. What is eutrophication? (2023, https://oceanservice.noaa.gov/facts/eutrophication.html)
[7] Wielard, Niels. HOW MUCH DEFORESTATION IS YOUR COTTON CREATING? (2021, https://www.the-sustainable-fashion-collective.com/2021/07/20/how-much-deforestation-is-your-cotton-creating)
[8] Sustainable Apparel Coalition. Higg Materials Sustainability Index (MSI) Methodology. (2020, https://howtohigg.org/wp-content/uploads/2020/07/Higg-MSI-Methodology-July-31-2020.pdf).

recycled material, **by two.** The numbers should be considered as indicators for how environmental impacts can be quantified, and in which ballpark the respective differences lie. In **Table 3**, it is seen that:

- **Recycled cotton provides huge savings in *water usage* and a large reduction of *eutrophication*** – when compared to both conventional and ecological cotton. It is also seen that the **dyeing process makes up a large portion of the environmental impacts**, especially in terms of: *global warming*, *depletion of fossil fuels,* and *chemistry*. **Dyeing should therefore be avoided** when mechanically recycling fibers, which is possible through our very accurate color sorting.
- For **conventional polyester**, the ***CO2 emissions* and *chemistry* are comparable to conventional cotton**. However, the ***water usage* is much lower** and there is a **lower degree of *eutrophication***. In return, the polyester is based on fossil oil, which causes a **larger *depletion of fossil fuels***, compared to cotton. As was the case for cotton, **significant savings can be achieved by using recycled polyester fibres**, especially when the **dyeing is avoided**.

Table 3: *Environmental impacts per kg. yarn, estimated for Ne30/1 yarn, not accounting for transport. Based on average values from the HIGG "Materials Sustainability Index" database.*	**Global warming**	**Eutrophication**	**Water usage**	**Depletion of fossil fuels**	**Chemistry**
100% conventional dyed cotton	10,3	17,7	58	8,28	12,1
100% ecological dyed cotton	9,12	9,54	7,04	7,69	9,42
100% recycled cotton w. dyeing	8,27	5,94	2,2	7,49	9,42
100% recycled cotton w/o dyeing	4,58	1,62	0,524	3,81	3,71
Reduction in impact of **recycled cotton w/o dyeing** compared to **conventional dyed cotton**.	56%	91%	99%	54%	69%
Reduction in impact of **recycled cotton w. dyeing** compared to **conventional dyed cotton**.	20%	66%	96%	9,5%	22%
Reduction in impact of **recycled cotton w/o dyeing** compared to **ecological dyed cotton**.	50%	83%	93%	51%	61%
Reduction in impact of **recycled cotton w/o dyeing** compared to **ecological dyed cotton**.	45%	73%	76%	49%	61%
100% conventional dyed polyester	11,5	3,82	1,52	14,3	9,53
100% recycled polyester w. dyeing	8,6	2,4	1,0	8,2	8,2
100% recycled polyester w/o dyeing	5,8	1,8	0,6	4,9	4,5
Reduction in impact of **recycled polyester w. dyeing** compared to **conventional dyed polyester.**	25%	39%	37%	43%	14%
Reduction in impact of **recycled polyester w/o dyeing** compared to **conventional dyed polyester.**	50%	52%	61%	66%	53%

NewRetex A/S is currently in a process of obtaining more thorough LCA-studies of our specific company and our products, in collaboration with environmental engineers from the Technical University of Denmark (DTU). These studies will provide more trustworthy assessments of the environmental impacts (and the savings) of our yarns.

5. Signatures

This report has been produced internally at NewRetex A/S by:

Rikke Bech, CEO	Andreas Lehmann Enevoldsen, Production Development Engineer

6. Appendices