Criteria and specifications guidelines for collection to meet yarn needs for sport garments

Deliverable 1.1

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Executive summary

- This document presents a first set of criteria and specifications on the material to be produced at the different stages of the pilot.
- The 3 recyclers have indicated a first set of specifications on each of the materials that will be recycled: cotton, polyamide & polyester.
  - **Common specifications**: no metal or hard points with a disassembled and shredded final material- eventually agglomerated.
  - **Polyamide specification**: the purest possible fraction, with a distinction between polyamide 6 (PA6), which is required in a very high proportion, and polyamide 6-6 (PA 6-6), which is not recyclable and must be present in the lowest possible proportions.
  - **Polyester specification**: a fraction of polyester as pure as possible without substances of concern such as PVC, which can degrade into corrosive hydrochloric acid and damage the process, cotton which, if present above the recommended threshold of 0,5 wt%, can stain the recycled material and elastane, which cannot be processed without additional preparation or removal (which is yet to be developed).
  - **Cotton specification**: currently the Infinited Fiber process is techno-economically suitable for textile waste fractions with a minimum of 88% cotton. The disassembling should remove, in addition to the hard points, the labels and prints made on the garments.
  - The **spinners** who will manufacture yarns from the recycled material have indicated that the polymer from the recycling process must be pure or it will not be processable.
  - **adidas** has quality constraints mainly due to international standards for the manufacture of clothing. On the one hand, the yarns used for the manufacture of clothing must meet international standards, and on the other hand the manufacturing stages of the garments must also comply with specific standards: mechanical properties, serviceability, colour tests, moisture management performance tests and flammability. The importance of these standards ensures the minimum standards for a textile to be selected as a part of a future adidas material library.
  - There are also **additional standards and specifications** for sporting goods for adidas such as:
    - Fineness of the yarn (to create the desired next to skin interaction expected by athletes and consumers)
    - Durability and resistance to washing (tested beyond other industries as clothing items are increasingly washed and experience increased wear during activities)
    - Functional properties of a textile such as moisture management, air permeability and thermal performance
    - Pure safety standards must also be met (flammability for example) to ensure adidas products are safe for consumers to use but also can be shipped globally as some markets do not allow certain chemicals or restrict materials.
  - The compilation of specifications has been completed, allowing us to clarify our collection, sorting and material preparation needs. The objective is now to make these specifications converge with what is actually achievable by the existing operators on the market.

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- The pre-established criteria and specifications will therefore evolve throughout the project. Partly, because of the increasing competence of the project's actors and partly because of a better understanding of the reality of the market's collection and sorting structures.

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1 Background/Objectives

This deliverable D1.1 is part of the implementation of WP1: "Textile Waste Collection & Assessment" of the T-REX project. The objectives of this work package are to collect the feedstock requested to pursue the project, while beginning the validation of the economic model. The collection must therefore respect the specified volumes and the expected composition, while taking place in the planned geographical areas. To do this, it is necessary to carry out an important work of synthesis and aggregation of the technical specifications of all the consortium's actors, before transmitting them to the field players who will carry out the various operations. It is also necessary to select from the solutions available on the market, the most likely to meet these specifications. To this end, Veolia, the Institute of Polymer Technology (LKT), CURE Technology, BASF, Infinited Fibre and adidas will work closely together on the various analyses to be carried out to ensure that the specifications are met at each stage of the value chain.

In Figure 1, the various steps of the project which allow, from the collection of used textiles, the production of recycled fibres for use in the production of new clothes, are presented.

- The post-consumer textile is collected in the French and Spanish territories, before being sorted, fractionated, and prepared according to the specifications established jointly with the recyclers of the consortium. It will then be recycled and spun to obtain a fibre that can be used by adidas.

- Throughout these stages, the Institute of Polymer Technology (LKT) will carry out analyses which are detailed in this report. These analyses will allow us to control the different operations but also to increase our knowledge on the composition and processing of textiles.

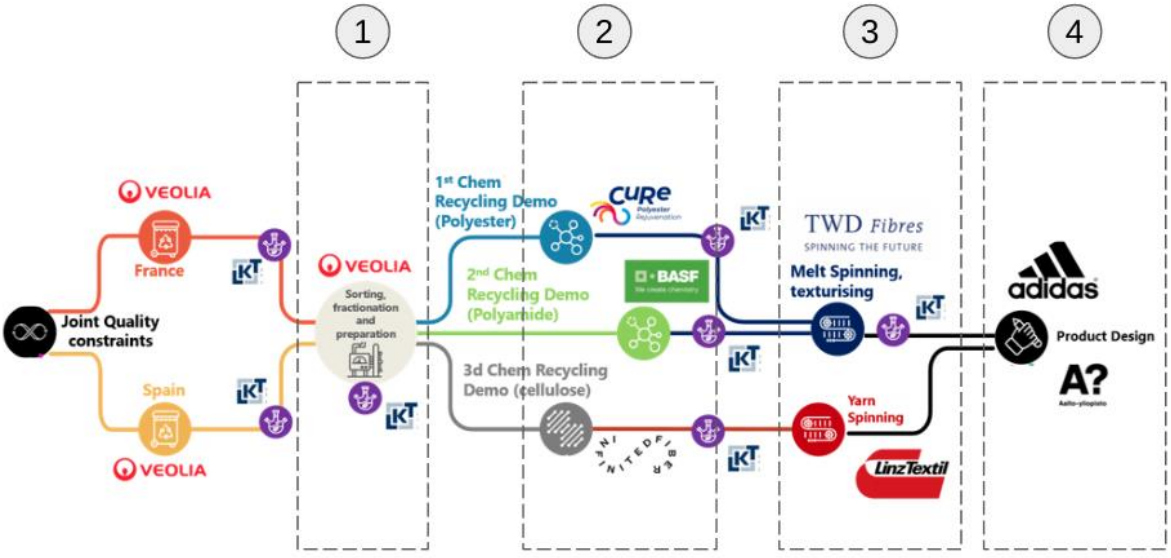

Fig 1: Description of the steps from feedstock collection to new fibres production

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- The Consortium specifications can be classified in 3 main categories:
    - The recyclers' processing constraints which define the quality of the textile material able to enter their recycling processes (n°2 on the diagram).
    - The spinners' manufacturing constraints which define the quality of the raw material that could be processed for the production of new yarns (n°3 on the diagram).
    - The quality constraints of adidas to allow the recycled textile to be used in the manufacture of new clothes (n°4 on the diagram).

- In parallel to securing sufficient collection volumes, a major objective of the project is to make the specifications of these 3 categories converge with what is actually achievable in terms of sorting, by the operators of the existing channels on the market. (n°1 on the diagram). It will be a difficult trade off to determine whether certain criteria can be modified without affecting the efficiency of recycling processes to ensure optimal preparation of raw materials.

To achieve this set of data, constraints, needs, the members concerned by this report (deliverable integrated in the WP1) meet every two weeks to anticipate the possible challenging points, enabling the good preparation of the feedstock.

2 Identification of the consortium members specifications

2.1 Recyclers' specifications - feedstock constraints

It should be noted that the specifications of the recyclers provided in this report may evolve during the project according to:

- possible changes in the recyclers' recycling process
- feasibility of reaching the proposed specifications for the collection and sorting external partners
- feedback from spinners or adidas on evolution of the manufacturing constraints

2.1.1 BASF specification

BASF recycles the polyamide 6 fraction of the pilot:

- For this purpose, the textile must be free of metallic materials and hard points (removal of metal parts with the disassembly process) and of the smallest possible fraction of materials other than polyamide (e.g. cotton, polyester and elastane).
- A special distinction is made between polyamide 6 (PA6) and polyamide 66 (PA66). In most cases, garments are either composed of PA6 or PA66, but they are seldomly combined in the same garment. Mixing occurs at a meta-level, i.e. in a container full of garments. BASF needs the highest possible fraction of PA6, as PA66 is not recycled in the process.

The material must be frayed and agglomerated to enter the recycling process.

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2.1.2 CuRe Technology specification

CuRe Technology recycles the polyester fraction of the pilot. CuRe Technology is still in development and more complex feedstocks will be possible later. At this stage, CuRe Technology does not yet have its own metal removal equipment, so for the time being the textile should not contain metallic material. However, over time and within the timeframe of this project, metals will be removed by CuRe Technology themselves.

- Most important is to have a low percentage of cotton and elastane, as well as other non-polyester textiles such as polyamide and acrylic as they will depolymerise and render the mixture difficult to properly repolymerise.
- Hard parts are preferably avoided but can be removed with the screening filters. PVC must be avoided as it leads to the formation of hydrochloric acid during its degradation, and this corrodes the metal of the equipment and thereby can cause safety concerns.
- The material must be shredded and agglomerated to enter the recycling process.

2.1.3 IFC specification

Infinited Fiber Company (IFC) recycles the cotton fractions of the pilot. The following specifications ensure successful chemical recycling and the profitability of the process from a techno-economical perspective:

- Metallic materials and other hard parts (e.g. zippers, buttons) should be removed
- Possible labels and impressions should be preferably removed, as they are often made from plastic materials
- The textiles must be shredded before entering the process
- The minimum cotton fraction of the material going into the IFC process is currently 88%. Smaller cotton fractions are also possible, but this decreases the profitability of the process.
- The resting 12% of the batch may consist of polyester, man-made cellulosic and small fractions of e.g., elasthane.

2.2 Spinner specifications - fabric constraints

2.2.1 TWD specification

TWD is the spinner on synthetic polymer streams (polyester and polyamide). From a technical point of view, it is imperative to have 100% pure fractions of polymer, which means that any impurities due to other textile fibres such as cotton or cellulose should be banned from the process. Same goes for impurities from metals or other polymers due to for example buttons or zippers or elastane.

- Colours/pigments are less critical as they mainly affect the final appearance/colour of the yarn but still some can interfere with the process and therefore limit the range of count numbers.

2.2.2 LINZ specification

LINZ is the spinner on the cotton stream. Their specifications focused on the dimensions of the fibres, including the titration expressed in dTex which is the unit of titration of textile fibres and filaments (here the dTex corresponds to the mass in grams of a length of 10,000 meters of

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product) and the length of the fibre. LINZ has tested Infinited Fibre's recycled fibres in the past, and they were able to indicate a titer between 0.9 and 1.7 dTex and a length of between 36 and 42 mm.

- Other constraints may occur as discussions with adidas on manufacturing specifications progress during the project.

2.2.3 adidas specification - clothes constraints

adidas has quality constraints essentially due to international standards for the manufacture of clothing.

- The yarns used for the manufacture of clothing must correspond to the needs with specific and precise criteria and respect international standards.
- adidas selected garments from their collection line that could incorporate recycled material (different garments according to polyester, polyamide, and cotton). This selection resulted in specifications on the manufacturing stages of the garments that meet adidas standards and international standards divided into the following categories:
    - Yarn standards such as linear density, tenacity, moisture content
    - Material standards, for example fabric weight in g/m^2
    - Mechanical properties, for example textiles abrasive resistance
    - Serviceability such as textile air permeability
    - Colour tests, for example wash fastness of a textile colouration
    - Moisture management performance tests
    - Flammability
- The importance of these standards ensures the minimum standards for a textile to be selected as a part of a future adidas material library.
- Critical standards and specifications in relation to sporting goods include:
    - **Yarn fineness** that is required to create the desired next to skin interaction expected by athletes and consumers. Filament counts >75 and denier per filament of <1 are challenging to melt spin, maintain the tenacity and abrasive resistance set out in the fabric requirements but are essential to achieving the target comfort in a final product.
    - **Durability** (snagging, abrasive resistance and tensile strength) and wash resistance are two areas that are tested beyond other industries as clothing items are increasingly washed and experience increased wear during activities.
    - **Functional properties** of a textile such as moisture management, air permeability and thermal performance are assessed against a combination of international standards that make up adidas's minimum requirements for a garment that is produced to perform in certain environmental conditions (warm, cold and wet).

Pure safety standards must also be met (e.g., flammability and assessment for band chemical ingredients). These ensure adidas products are safe for consumers to use but also can be shipped globally as some markets do not allow certain chemicals or restrict materials.

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3 LKT in material analysis throughout the recycling process

The Institute of Polymer Technology (LKT) is responsible for performing several analyses on material samples after the collection (included in WP1), sorting / material preparation, recycling and spinning stages.

- For this WP1, the goal is to find out what is the average composition of the collected material. They will develop the according testing procedures.
- The current plan is to perform thermo-analytical, chemical, and physical tests. It will be successful if our samples behave like polymer blends.
- The main following testing will be done:
  - DSC (differential scanning calorimetry): measure the melt- and crystallization temperature. This is characteristic for our relevant polymers (PES/PA6.6/PA6) will help us to verify the presence of these materials in a sample.
  - TGA (thermo gravimetric analysis): measure the degradation temperature of the sample. Again, this is characteristic for each material and will help to compute a quantitative statement about the composition.
  - Wet chemical analysis: selectively dissolve some components and through weighting the residual, compute the composition.
  - Fourier-transform infrared (FTIR) spectroscopy: measure the presence of certain polymers. A quantitative determination is not directly possible, but with a systematic approach over a larger number of samples we hope to be able to create a better understanding of the composition of the collected material.
  - Microscopic investigations to optically investigate specific material samples.

- In order to increase the precision of the wide range of testing, material should be finely shredded and as homogenous as possible, to reduce the deviations between different samples.
- However, this is only a starting point and some other waste characterization procedures could be added along the way.

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4 Useful data for the other work packages of the projects

The operational part of closed-loop textile recycling (integrated in WP1: "Textile waste collection & assessment", WP2: "Sorting, fractionation & preparation" and WP3: "Recycling demonstrators & yarn spinning") is only one component of the T-REX project. WP4: "Business viability & sustainability", WP5: "Design guidelines", WP6: "Citizens' engagement & knowledge transfer" and WP7: "Digital solutions" will feed on information and feedback from the operations conducted.
This is why we have exchanged with these other workgroups, to clarify and specify their needs, which will also be shared with the selected collection and sorting actors. The data collected should allow for example: the analysis of the life cycle, the analysis of the problems encountered, the choice of material, recommendations to improve the market structure, amongst other factors.

5 Initial findings on the structure of the textile sector

In parallel with internal specification and needs collection and aggregation, Veolia is conducting the first discussions with market players in the French and Spanish territory, to identify the different parties involved in collection and sorting.
The collection and sorting actors have been identified and contacted to increase our understanding of their own issues. It also helped us to clarify the market structure and the best way to work with them in the framework of the pilot.
Here are listed a first set of information that will help to highlight and address the challenges of the current specifications required by our downstream consortium activities:

- The sorting in these structures is done manually. First, the reusable fraction is sorted (called the "cream"), essentially by operators working in social and solidarity economy companies (SSE). Then a second step of material sorting is also usually done manually, with sometimes the assistance of a handheld material recognition device.
- The handheld material composition recognition device is a detection device based on near-infrared spectroscopy technology (0.78 to 2.5 µm wavelength range). The scanners are able to detect the presence of multiple fibre types - all based on the type of materials library that is loaded onto the device (which usually have multiple mixes) The most commonly used systems on the market still have important limitations:
  - The wavelengths do not penetrate the material, so it only analyses the surface of the fibre. Fibres are sometimes mixed and woven in such a way that one material is not detectable because it is "coated" with other threads of a different material.
  - Multi-layered garments are a problem. They can be scanned in layers but this requires the whole garment to be disassembled, otherwise the scanner will only give the composition of the surface material.
  - The detection is done on a small area of the garment, which sometimes is not representative of the total composition of the garment.
  - Due to the dyes/coatings used, it works with difficulty on black and dark garments.

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- The differentiation of polyamide 6 from polyamide 6-6 is mainly being developed by some handheld material recognition technologies and automated sorting technologies. This is a point of vigilance that must be kept in mind for BASF's specifications. In the panorama of recognition technologies, we are looking at those that develop this aspect because it will be useful for sorting and preparing the polyamide.

The best method to determine the composition of the material is chemical analysis, but it is not suitable for sorting because it is expensive and very time consuming.

The available volumes of polyamide are low in the collected deposits. Cotton and polyester dominate in the deposits, but 90% or more pure polyamide is present in small quantities, which also raises the problem of obtaining the volume necessary for the pilot. Discussions are underway to validate the maximum volumes available and perhaps mutualize the collections on this fraction for the pilot.

Understanding that the majority of actors perform the sorting manually, we are looking at companies and projects of automated textile sorting. The objective is to understand the operation, the advantages, the points of improvement of the different technologies currently on the market and if it is relevant to consider this specific step of automated sorting in the stages of sorting / preparation of the material for the project.

The sorted material should be single layer as multi-layer garments are more complex to identify (often with different materials per layer) and would need to be disassembled which represents a significant amount of time and resources in material preparation as there is currently no business case for manual disassembly in Europe and there is no automated disassembly tech at scale. It is for more ease and speed that it is preferred to choose single layer garments.

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6 Conclusions

This first step of gathering and converging the different criteria, constraints, and specifications on all the stages of the project is essential to achieve the final objective of manufacturing new clothing from recycled textiles.

The specifications formalized by the 3 recyclers, made it possible to clarify our needs with the specialized operational players for the collection, sorting and preparation of the material, without deteriorating the final quality of the products obtained. The objective is now to make the needs of recyclers converge with what is currently achievable on the market.

Veolia has already met with a large panel of players and is beginning to engage in discussions in order to select the most effective solution for achieving all of the defined objectives.

The criteria and specifications retained will certainly evolve throughout the project, with the rise in skills of the consortium and the finer understanding of the market structure. Regular exchanges between consortium members are essential to anticipate and modify this set of criteria in order to achieve textile closed loop recycling.

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