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RECYCLING OF WASTE ACRYLIC TEXTILES

D6.3: Recommendation for technology transfer

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Abstract	Recommendations about product and production chain design, about best sustainable finishing obtained thanks to the outcomes of the project about finishing removal, hazardous substances treatment and disposal and about mechanical recycling process
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Acknowledgment

** REPORT: Document, report (excluding the periodic and final reports)*

DEM: Demonstrator, pilot, prototype, plan designs

DEC: Websites, patents filing, press & media actions, videos, etc.

OTHER: Software, technical diagram, etc

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EXECUTIVE SUMMARY

This deliverable has been created in the context of the WP 6 (LCA and recommendations) of the H2020-funded project REACT (Grant No. 820869).

The document provides an overview of the work done in the whole project and the recommendations for transfer the existing technology to develop a production chain of recycled acrylic fabrics. The document provides indications on how to manage waste generated in the production phases and recovery systems of the material at the end of its life, the technology used to remove the chemicals, the disposal and treatment of hazardous substances and the modification of mechanical recycling process to treat the acrylic fibres.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLE

ABBREVIATIONS

API	Active Pharmaceutical Ingredients
COREPLA	Consorzio nazionale per la raccolta, il riciclo e il recupero degli imballaggi in plastica
COMIECO	Consorzio nazionale recupero e riciclo degli imballaggi a base cellulosica
FDA	Food and Drug Administration
LCA	Life Cycle Assessment
NIR	Near Infrared Spectroscopy
PAT	Process Analytical Technology

1 INTRODUCTION

The results of the project will generate new references to develop whole acrylic recycled textile production chain for outdoor sector. The production process is designed and set-up with the final product specifications, but modification be made to use existent machines, not only textile sector but including technology from another sector.

The removal of finishes from acrylic fabrics, the main objective of the project, took the greatest amount of time over the 3 years, this led to limiting the surrounding activities, such as waste management and the destruction and recreation of fabrics. Overcoming this time limit has led the consortium to rely on existing technologies in the textile sector and not only for the development of all those related activities, with the ultimate aim of creating a consolidated supply chain for the recovery and recycling of acrylic fabrics for outdoor use. The technological transfer towards the REACT supply chain has made it possible to limit the time required for the creation of new plants and to create a system for the management, separation, treatment, fraying, spinning, weaving and finishing of the waste acrylic fabric in the time period of the project.

The document will describe the technologies transferred from their normal use to meet the needs of the project and the objectives set by creating an active supply chain for the production of recycled acrylic fabrics.

2 TECHNOLOGY TRANSFER

2.1 Waste management and collection

The new package of circular economy directives provides for the obligation to separate textile waste. For this reason, the waste recovery procedures must be implemented to reach the starting date of the directive with a consolidated method for the management of textile waste. In the REACT project, the starting point was the implementation of a waste collection management system.

The management and collection of waste from the production process of yarns and fabrics by both weavers and manufacturers of awnings or furnishing products can be managed within the same company and in some cases with the reintegration of waste in the production chain without further processing. If there are no problems from the point of view of the collection of waste from the production process of yarns and fabrics, some more problems may be encountered in the recovery phase of the material at the end of its life. The large manufacturing companies of awnings directly supply a large number of installers and customers. The assembly is generally done by the same installer who collects the old awnings who very rarely returns them to the manufacturer and then ends up in the landfill. An innovative management system capable of recovering the maximum quantity of fabric should guarantee transparency and knowledge to the entire fabric use chain, informing the final consumer of the possibility of recovering the material at the end of its life. The specific documentation provided to the customer at the time of installation, which describes the methods of returning the material, can be implemented as a way of raising awareness of users.

Today all the participants in the outdoor world supply chain, from spinning to the end customer, send waste in various forms to landfills paying a cost for collection and disposal. In the near future, when the REACT project has fine-tuned and verified the possible reuse of chemically treated and frayed waste, it will be possible to implement the following recovery scheme. Waste (spinning, weaving, manufacturing companies) and post-consumer materials recovered by installers could be conveyed to a single platform-consortium that collects the material for free, similarly to Italian consortia active in recycling in certain sectors such as COREPLA (Consorzio nazionale per la raccolta, il riciclo e il recupero degli imballaggi in plastica) or COMIECO (Consorzio nazionale recupero e riciclo degli imballaggi a base cellulosica).

2.2 Sorting textile waste

A fundamental problem to be faced is the proper separation of materials that prevent possible contamination or managerial ambiguities. The waste must be categorized in a distinctive way with easy-to-understand labels and initials to avoid the problems described above and send them to the appropriate method of removing the finish based on their chemical characteristics. At the moment in the textile sector this type of procedure is done manually with only some cases of automated processes. To address this problem, the project developed a recognition process using NIR spectroscopy, transferring the method from sectors where this identification is already widely implemented. In fact, NIR technology coupled with chemometric methods is widely used in the pharmaceutical and food sectors for on-line control of raw materials, process and final product.

The U.S. Food and Drug Administration (FDA) and European Union health guidelines have increased the workload and rigor associated with content inspection, mixing, and dosing. With the advent of 100% container testing for receiving raw materials inspection in Europe and Canada, NIR technology can reduce the time and skill level required to meet the growing compliance challenge.

With the Process Analytical Technology (PAT) initiative, the FDA aims to drive efficiency gains in pharmaceutical manufacturing, including a tendency to move away from final controls towards real-time process control and analysis. The initiative calls for rapid analytical techniques that allow for complete online monitoring of the manufacturing process. To this end, NIR is the most powerful analytical tool currently dominating all PAT projects.

Common pharmaceutical applications using NIR include:

- inspection of excipients and active pharmaceutical ingredients (API)

- mix uniformity
- granulation
- drying and coating
- particle size analysis.

Additionally, NIR is an invaluable tool for detecting counterfeit pharmaceuticals and determining residual water and solvent content.

The food and beverage production process chain are practically divided into five steps, starting with the receipt of goods, continuing with the inspection of incoming products, production and quality control, up to logistics and distribution. Along this chain, the quality of raw materials, semi-finished products and final products is subjected to regular checks. At certain stages of the inspection on incoming products, samples are taken and further analysed in relation to relevant quality parameters.

By implementing rapid measurement technology, out-of-specification raw materials - which could result in costly process deviations or degraded finished product quality - can be flagged as soon as they reach the loading dock. In addition, the volume of inspected incoming goods can be significantly increased with fewer resources and lower costs than traditional methods, overcoming some of the risks of random sampling. The application of NIR sensors online or in-line provides the added potential for continuous and automated quality measurements at various points of the installation along the production chain, from the acquisition of the raw material to the release of the finished product.

On the basis of these evidence in sectors completely different from textiles, the project implemented a recognition method customized on the design purposes, creating a NIR-chemometric model capable of recognizing the type of finishing present on the acrylic fabric and the recognition if a fabric is pre - or post-consumer. In this way, the production process is able to separate the fabrics based on the chemical characteristics of the finishing and direct it to the appropriate processes capable of removing the finishes themselves at maximum efficiency.

2.3 Finishing removal process scale-up

The scale-up of a process consists of all the considerations and actions necessary to reproduce laboratory data at an industrial level and represents the methodology for developing a chemical process. The reasons why it is not automatic to replicate laboratory data at an industrial level are the following: the reagents have different purities, the materials of the equipment are different and there are phenomena that depend on the dimensions, such as mass transfer and heat. However, it is possible to identify processes where the problems in the scale-up are more significant and are the following: exothermic and endothermic reactions; reactions where there are mass transfers (gas-liquid, liquid-liquid, gas-liquid, solid-gas or liquid-solid reactions).

In the case of the REACT project, the problem related to the purity of the reagents does not exist, since the reagents used in the lab scale for the most efficient finishing removal process were supplied by Soft Chemicals and are the same used for the large-scale process. Considering the results obtained in the development of the process in lab scale and the desire to use existing machines in the textile supply chain, it was decided to exploit the machines used for dyeing.

In the REACT project we have decided to use machines for the processing of staple and / or yarn, as it is more suitable for the type of process developed in the lab scale. These are equipment used for the dyeing of textile fibers in staple or more frequently in yarn in its various forms of winding such as cone, focaccia, etc. The use of interchangeable modular material holders allows flexibility in loading and dyeing packages of different diameters. Considering the fibrous nature of the material, the machine was equipped with suitable material holders consisting of metal baskets. The machines are equipped with automation systems, such as automatic loading and unloading devices above the device, centrifugation and drying systems, in order to meet the ever-increasing needs for process optimization. We used an autoclave machine that is used for the dyeing of textile fibers in staple and yarn in the various forms of winding (cones, focaccia, beams, etc.).

The autoclave used is of the vertical type, the bath is kept in circulation by pumps that can be centrifugal or helical: these pumps must guarantee and maintain a bath flow through the material, so that the surface of the fiber is in a state of saturation with respect to the dye. To do this, they must overcome all the resistances deriving from pipes and the resistance of the material itself (pressure drop) and at variable times reverse the direction of circulation of the bath to ensure uniformity of dyeing.

2.4 Spinning process

Awnings and outdoor fabrics are manufactured with acrylic yarns and require specific properties as they can pass through following chemical treatments (such as UV or water repellent treatment) and, more important, they have a long outdoor life with the exposure to atmospheric events. The yarn used for this kind of fabrics is usually manufactured with ring spinning.

At the same time, based on the experience on non-acrylic recycled fibres made by different market players that acknowledge open-end spinning as more suitable for the scope, the project was set in order to have also trials with this technology; although it was evident that there was the opportunity that produced yarn couldn't have the same features of the ring spinning yarn.

Although both technologies have the same first production steps, they differ very much in the following stages and provide different results in terms of yarn properties and yield.

The first one, open-end spinning, offers high productivity and low power consumption; it can easily manage short fibres and it is generally used to manufacture harsher and coarser yarns.

The second one, ring spinning, requires more mechanical steps from fibre to yarn and the production rate is lower than open-end. It also requires more power consumption and men work. At the same time, this process allows yarn to have higher quality in terms of tenacity, strength and a softer handle.

The basic difference between ring-spun yarns and open-end spun yarns is in the way they are formed. The former produces yarn by inserting twist into a continuous ribbon-like strand of cohesive fibres delivered by the front rolls, while the latter forms yarn from individual fibres directly by collecting them from the inside surface of a rotor by twist forces.

3 CONCLUSIONS

In the REACT project, technology transfer was an important and necessary part to get to an end with the creation of a production chain for recycled acrylic fabrics, going to acquire technologies and processes present in other sectors or going to find technologies in the textile sector that are not usually used. for the purpose conceived in the project but modifying them appropriately to obtain the predetermined results. The main purpose of the project was not to be hindered by the production of new and customized plants, but the necessary technologies had to be implemented and absorbed by other processes.

The final result demonstrates how technological solutions can be found within the same sector by using ingenuity to adapt the technology to use and not vice versa, or by exploring sectors that are far from the one on which we focus. REACT can therefore be taken as an example of this philosophy by transferring textile processes within the supply chain not developed for the purposes for which they were used and by introducing technologies used in the packaging, pharmaceutical and food sectors, adapting them to the design purpose.