UNIVERSITÀ DEGLI STUDI DI BERGAMO | Dipartimento di Ingegneria e Scienze Applicate

REACT

Nano Innovation 2022 Rome, 19-23 September Conference & Exhibition

STRATEGIES FOR REMOVING CHEMICAL FINISHES FROM POST-CONSUMER OUTDOOR FABRICS

New products or manufacturing process development

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STRATEGIES FOR REMOVING CHEMICAL FINISHES FROM POST-CONSUMER OUTDOOR FABRICS

- ✓ **INTRODUCTION**
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  - PRELIMINARY STUDIES ON QUALITY CONTROL FABRICS
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INTRODUCTION

REACT

REcycling of **AC**rylic **T**extile waste

(36 months duration – June 2019 – September 2022)

H2020 – SC5-2018-2019-2020

Methods to remove hazardous substances and contaminants from secondary raw materials

The REACT proposal will address the **management** of waste acrylic textiles coming from **outdoor awnings** and **furnishing**.

INTRODUCTION

REACT

REcycling of **AC**rylic **T**extile waste

(36 months duration – June 2019 – September 2022)

European Commission

H2020 – SC5-2018-2019-2020

Methods to remove hazardous substances and contaminants from secondary raw materials

The goal is to perform a new process for **hazardous chemicals removal** from finished acrylic textiles, with **innovative investigation and processing techniques** in order to obtain a **fully compatible recycled acrylic textile for reuse**.

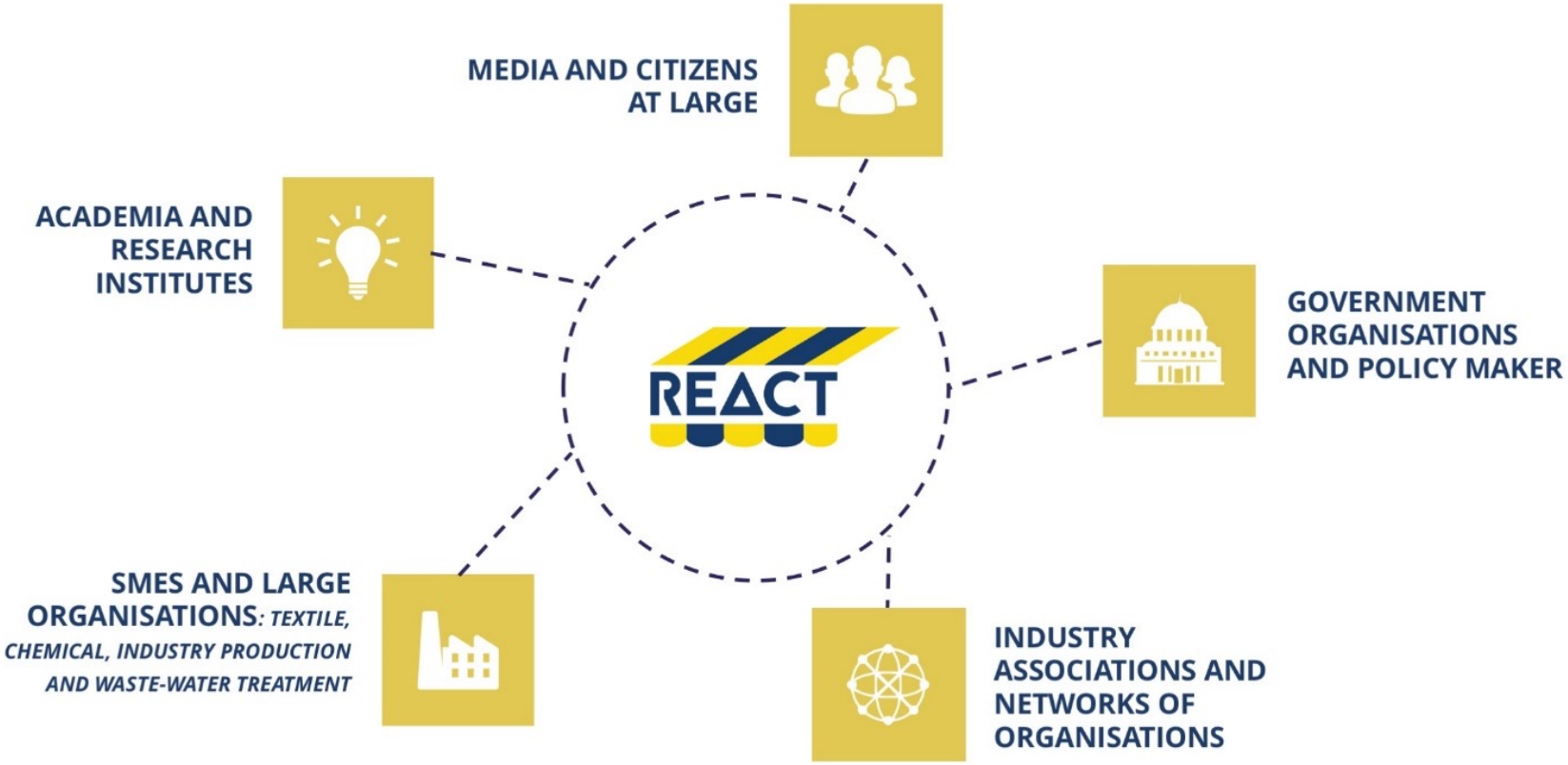
INTRODUCTION

Innovation expected from REACT project activities are concerning:

- ✓ Post-consumer waste treatment (e.g. **chemical finishes removal**) to **enhance their recycling;**
- ✓ **Innovative analytical method** for the identification of chemicals;
- ✓ **Innovative approaches** to improve **sustainability** and reduce environmental and health risk.

INTRODUCTION

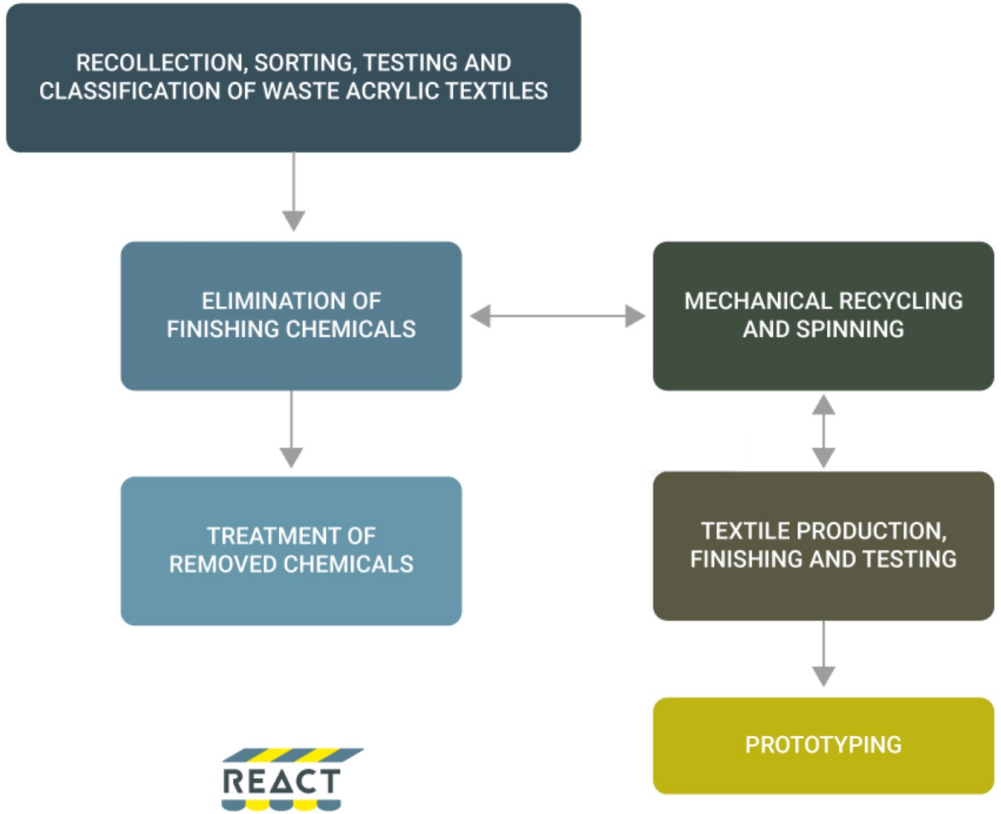
REACT project involves **stakeholders** and **market**:



INTRODUCTION

The **long-term purposes** of REACT project can be summarized as follows:

- ✓ To produce **recommendations** on:
  - production chain implementation;
  - design and manufacturing of materials to enhance recyclability;
  - technology transfer and standards.
- ✓ A **circular economy approach** to:
  - improve secondary raw material recovery;
  - find new methods to avoid hazardous materials in recycled acrylic goods.



INTRODUCTION

The **goals** of REACT project are:

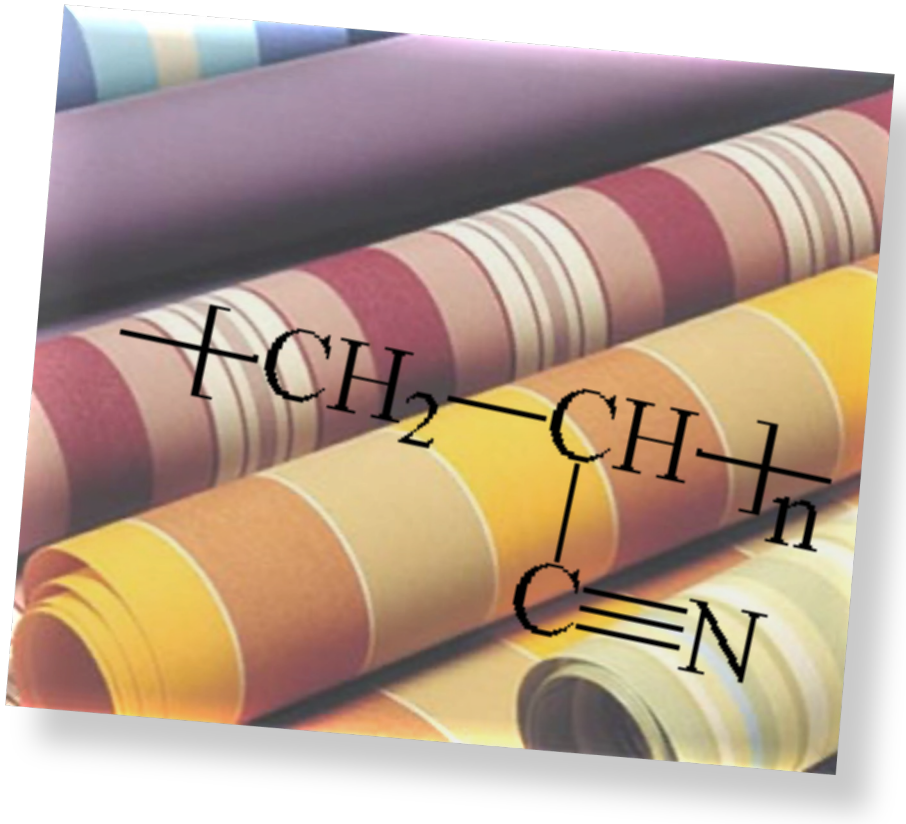
- ✓ **To reach a removal rate** of **90-95%** of hazardous chemicals that prevent fibre recycling;
- ✓ To obtain a final textile product with yarn coming from **100% recycled fibre**, mixing regenerated fibres from card, winding opened thread and waste material collected fibre, each up to 33%;
- ✓ To treat up to **99% of all** sewage **impurities** obtained from removal steps;
- ✓ To reuse the acrylic textiles as raw material for other production cycles, to reach 30% **of waste prevented** from disposal **(3.600 tonnes total/year)** for the outdoor sector (awnings and furnishing).

INTRODUCTION

REACT project activities were focused on the removal of contaminants from **acrylic fibres.**

Due to their **unmatchable performance** (combination of weatherability and mechanical strength), it is **the mainly used fibre (>90%) in awnings and outdoor furnishing:**

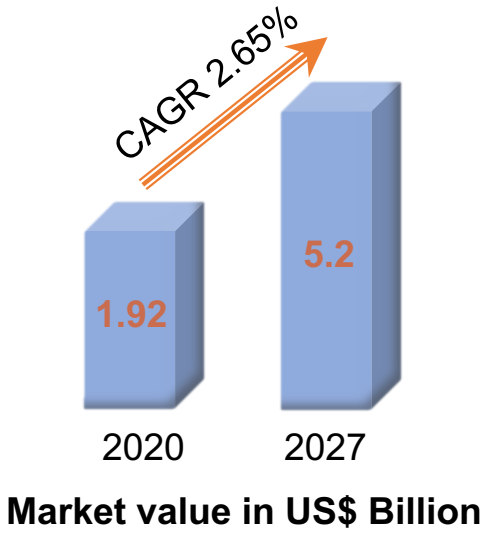
- **11'000 tonnes/year** of outdoor acrylic textiles;
- **2.5 million awnings installed in Europe**;
- **7'700 tonnes/year** of acrylic textile waste are disposed of by **landfill or incineration**.



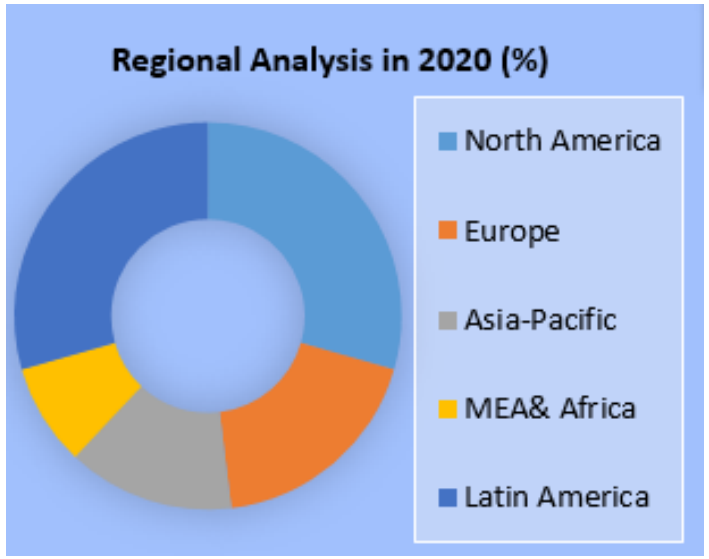
INTRODUCTION

REACT project activities were focused on the removal of contaminants from **acrylic fibres.**

- ✓ The global acrylic fibre market is projected to reach a market value of about **US$ 5.2 billion by 2027** end, registering a **CAGR of 2.65%**



Market value in US$ Billion

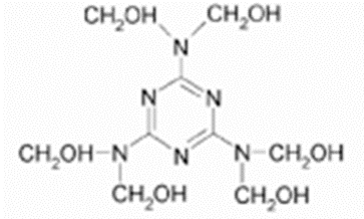


https://www.maximizemarketresearch.com/market-report/global-acrylic-fibre-market/64998/

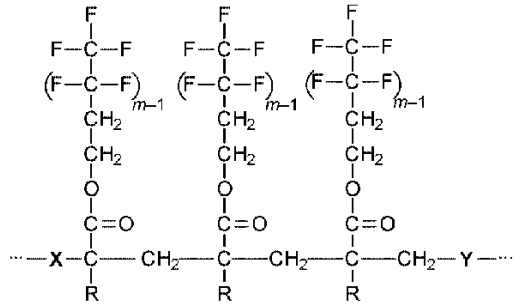
INTRODUCTION

For outdoor applications, the commonly used synthetic fabrics are **finished with specific chemicals** to increase their resistance to atmospheric agents and make them long-lasting water-resistant.

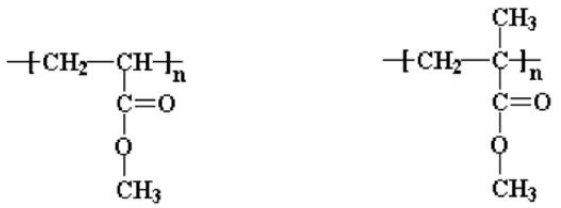
Melamine-formaldehyde, acrylic and fluorocarbon resins are among the most commonly used finishes for this purpose.



Melamine-formaldehyde resins



Perfluorocarbon resins (PFC)



Acrylic resins

INTRODUCTION

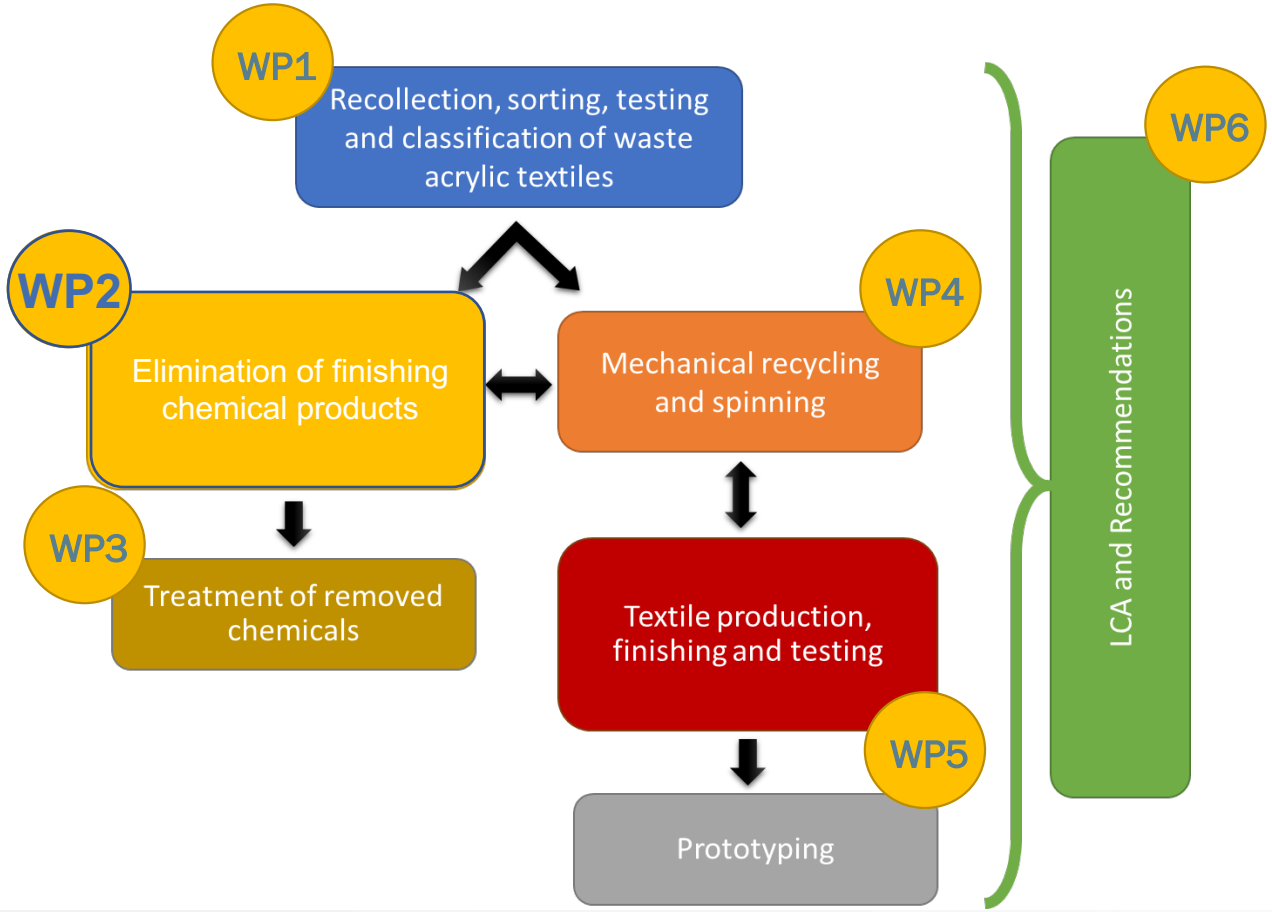
- ✓ Carcinogenic, mutagenic or toxic for reproduction
- ✓ Persistent, bioaccumulative and toxic substances (PBTs)
- ✓ Very persistent and very bioaccumulative substances (vPvB)

Recycling acrylics fabrics produced many years ago, probably a lot of these substances will be **removed and replaced** on the market with more **environmentally friendly chemicals**.

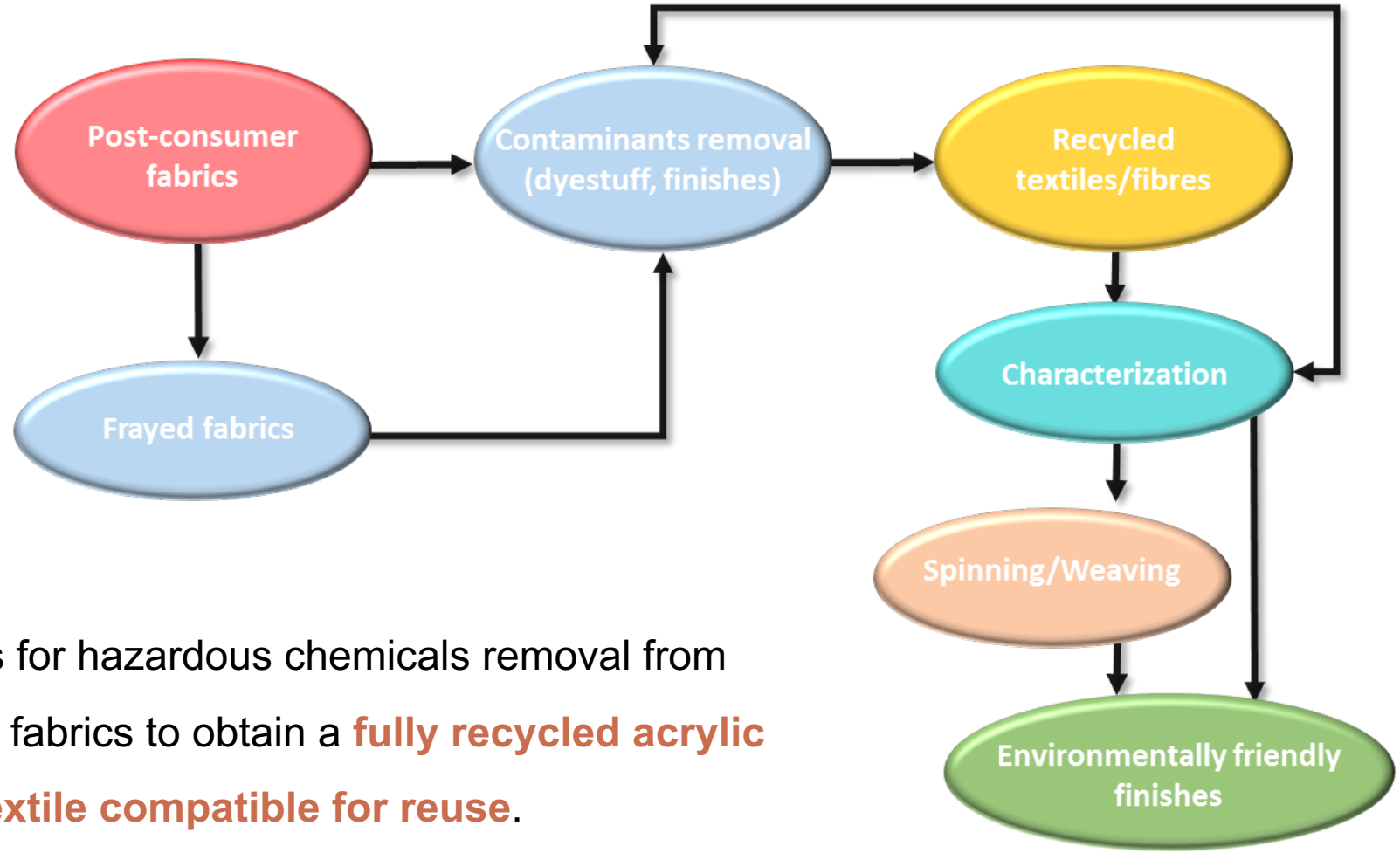
Contextually, the **safe utilization and disposal** of the **removed substances** will be implemented to ensure **sustainability** and **reduce environmental and health risks**, as stated in Regulation (EC) No 1907/2006 (REACH).

INTRODUCTION

REACT project activities:

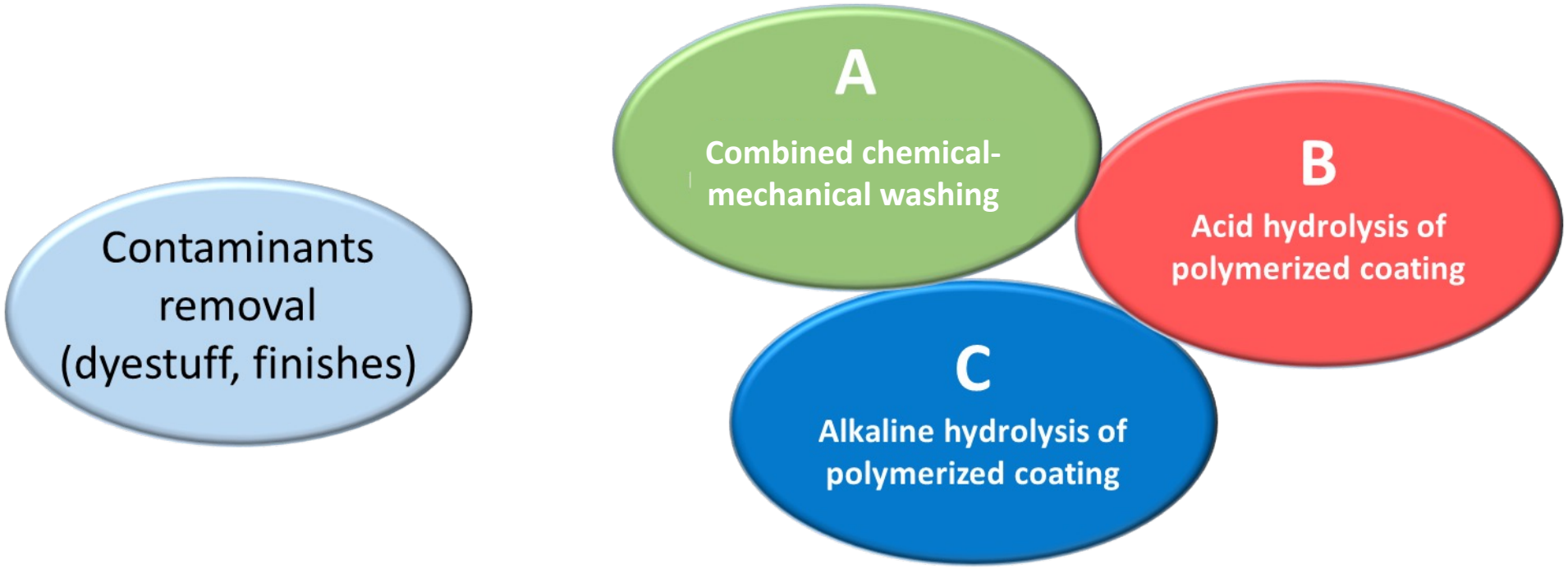


CONTAMINANTS REMOVAL FROM ACRYLIC FABRICS



New process for hazardous chemicals removal from finished acrylic fabrics to obtain a **fully recycled acrylic textile compatible for reuse**.

CONTAMINANTS REMOVAL FROM ACRYLIC FABRICS



The removal of finishing products is carried out by chemical attacks under wet conditions (photodegradation).

To remove finishing coatings, a combination of chemicals and mechanical actions (A, B, C investigated) involving swelling and dispersing agents, studying the pH influence.

CONTAMINANTS REMOVAL FROM ACRYLIC FABRICS

PRELIMINARY STUDIES ON QUALITY CONTROL FABRICS

In particular, the following finishes were removed:

"A"

THERMOSETTING RESIN
FLUOROCARBON RESIN

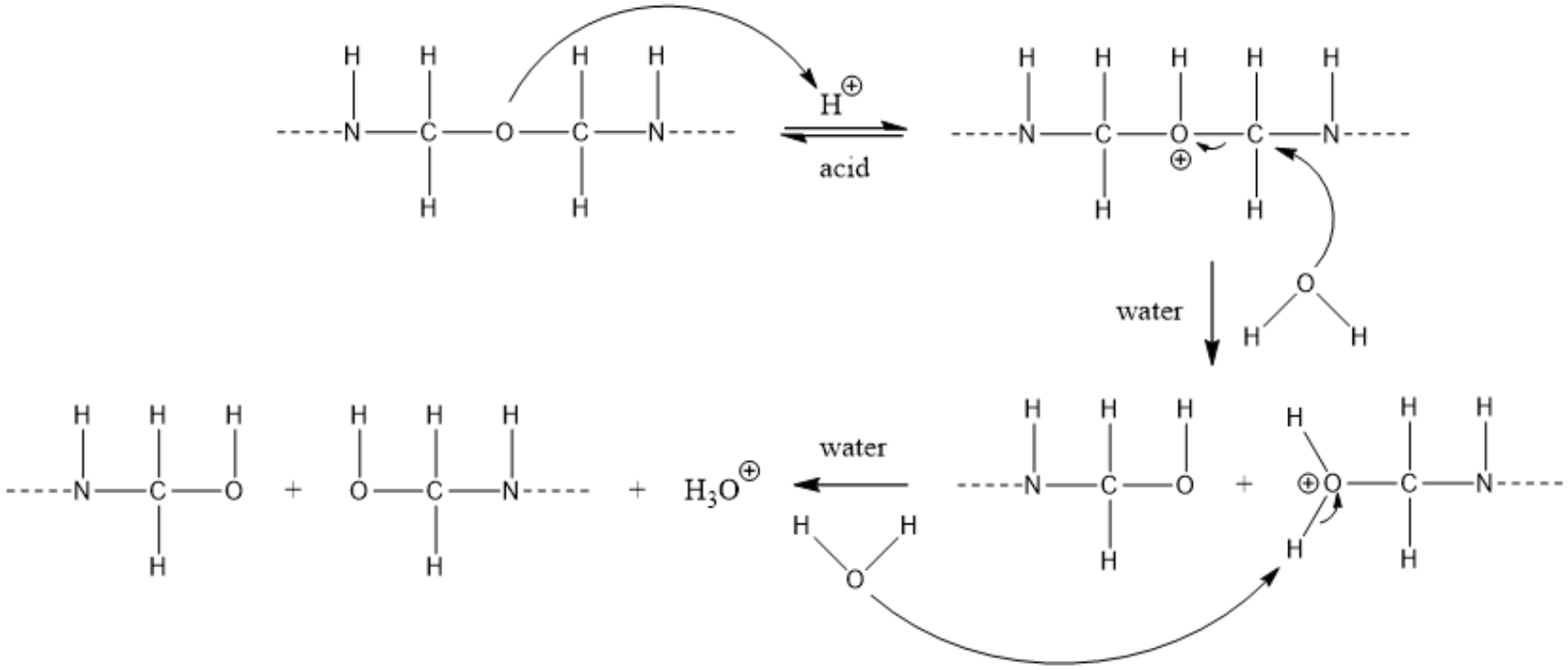
"B"

THERMOSETTING RESIN
FLUOROCARBON RESIN
WATERPROOF COATING

CONTAMINANTS REMOVAL FROM ACRYLIC FABRICS

PRELIMINARY STUDIES ON QUALITY CONTROL FABRICS

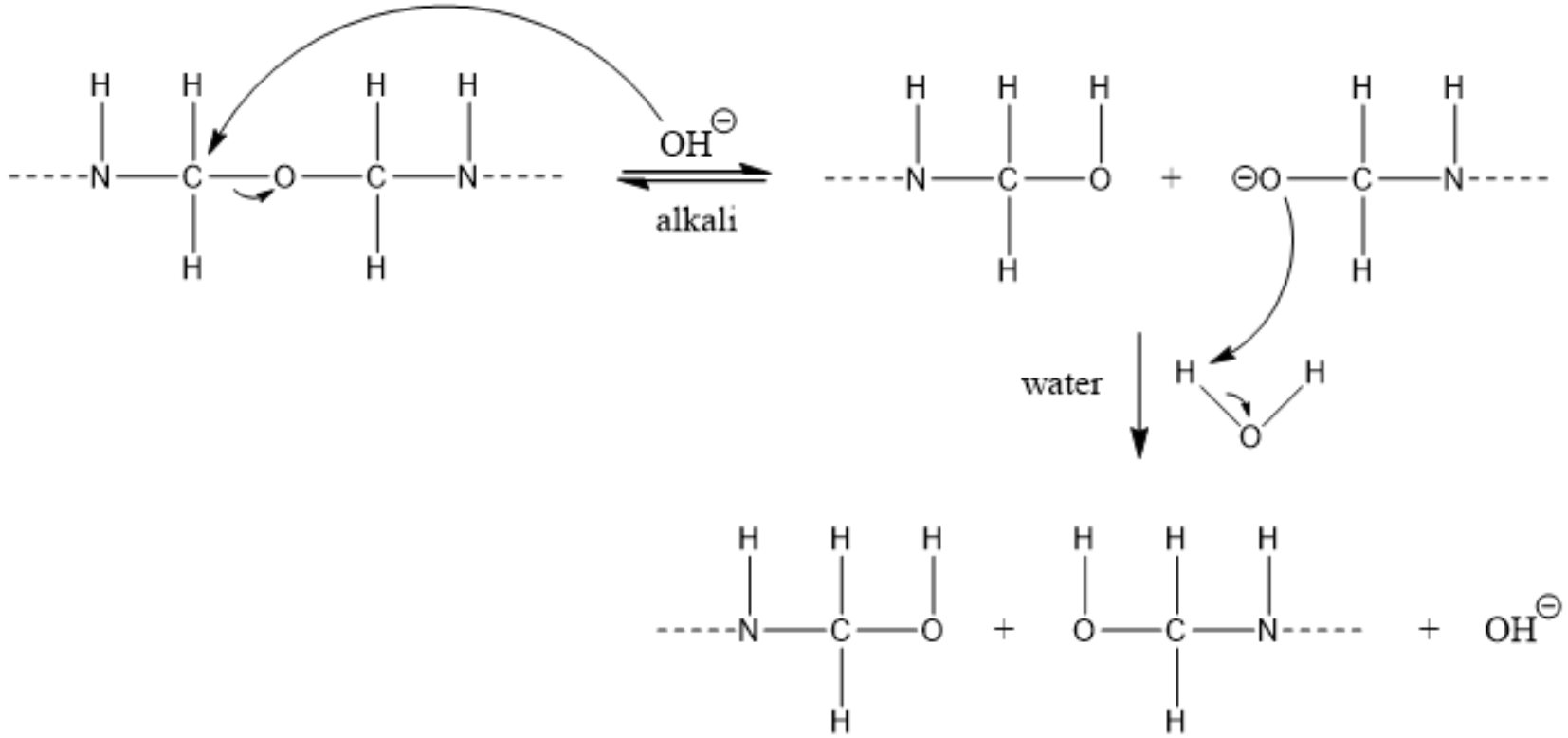
Proposed mechanism of bond cleavage by **acid hydrolysis**



CONTAMINANTS REMOVAL FROM ACRYLIC FABRICS

PRELIMINARY STUDIES ON QUALITY CONTROL FABRICS

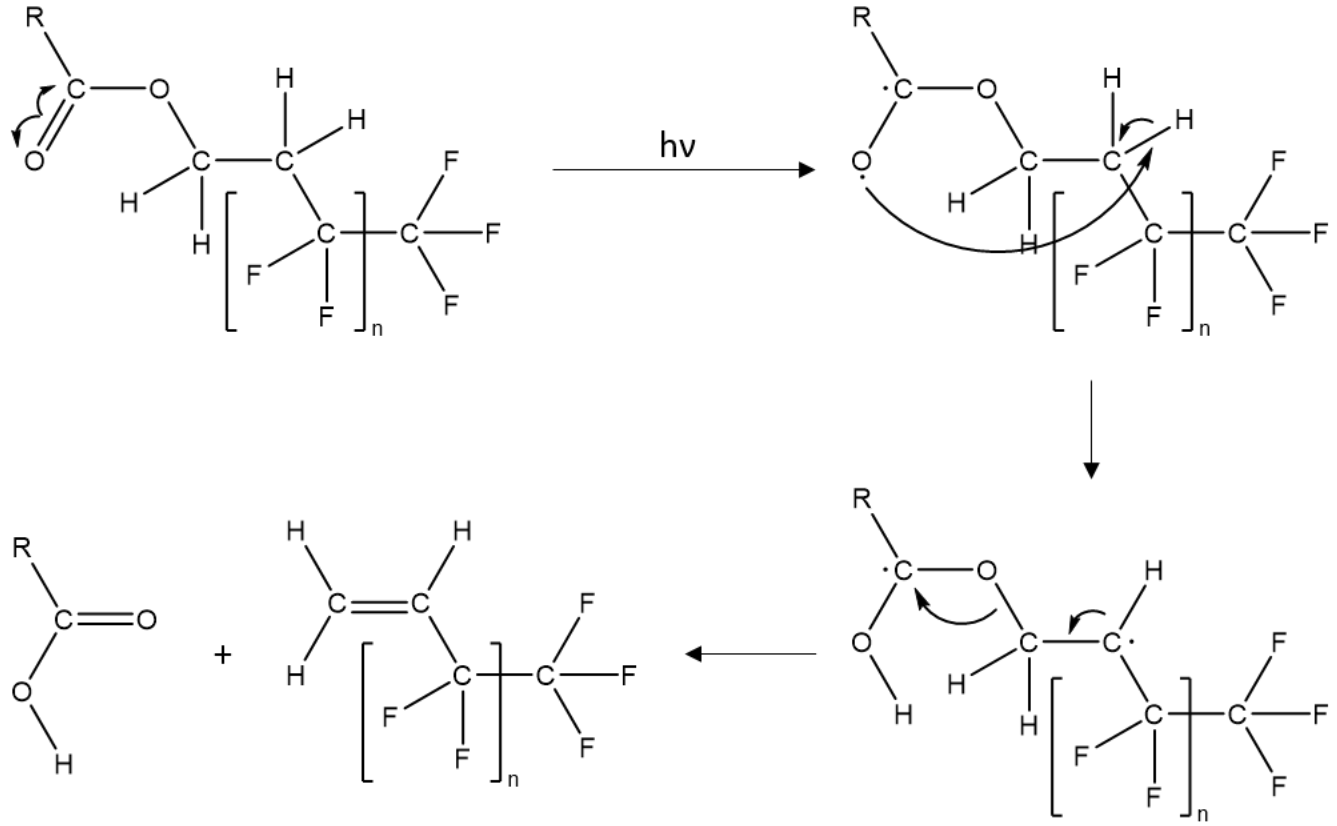
Proposed mechanism of bond cleavage by **alkaline hydrolysis**



CONTAMINANTS REMOVAL FROM ACRYLIC FABRICS

PRELIMINARY STUDIES ON QUALITY CONTROL FABRICS

Proposed mechanism of bond cleavage by **photolytic degradation of fluorocarbon resin**



CONTAMINANTS REMOVAL FROM ACRYLIC FABRICS

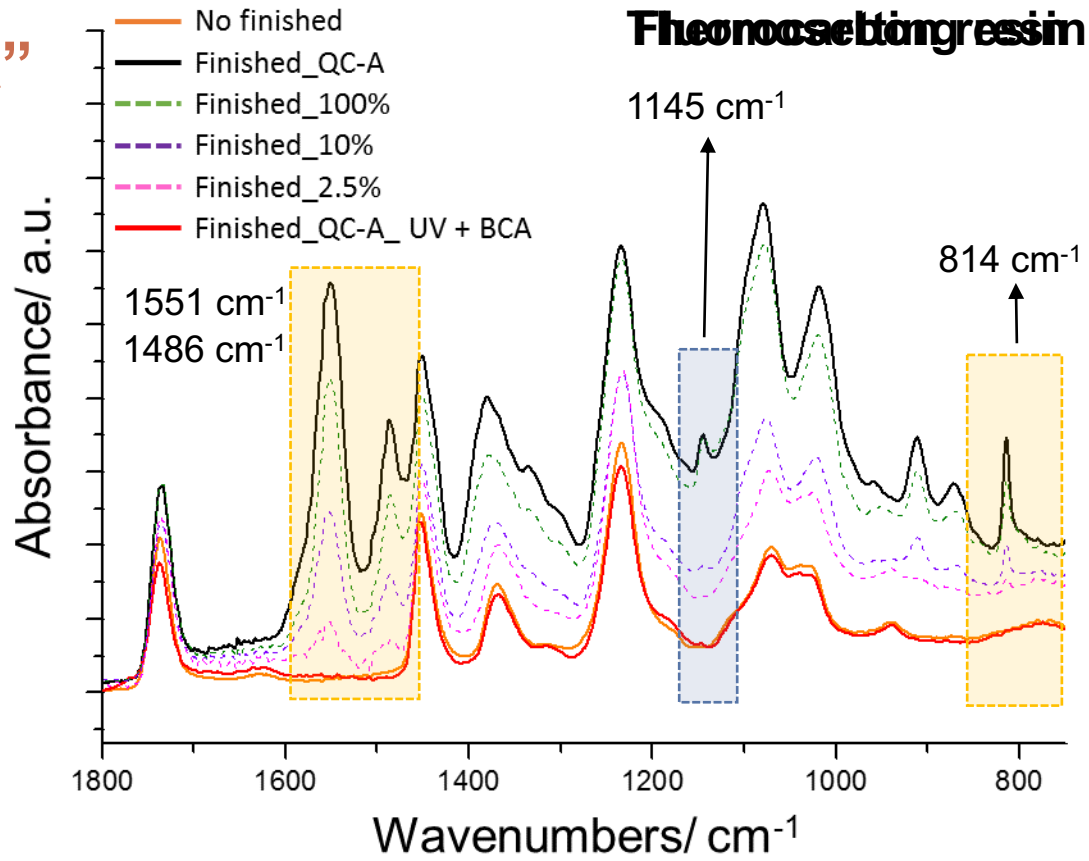
PRELIMINARY STUDIES ON QUALITY CONTROL FABRICS

Preliminary laboratory experiments have shown that the combination of the three chemical processes, supported by the photoirradiation of fabrics, is responsible for **over 90%*** removal of the applied finishing **"A"**.

*calculated on the basis of calibration lines

ATR - FTIR characterization

"A"



CONTAMINANTS REMOVAL FROM ACRYLIC FABRICS

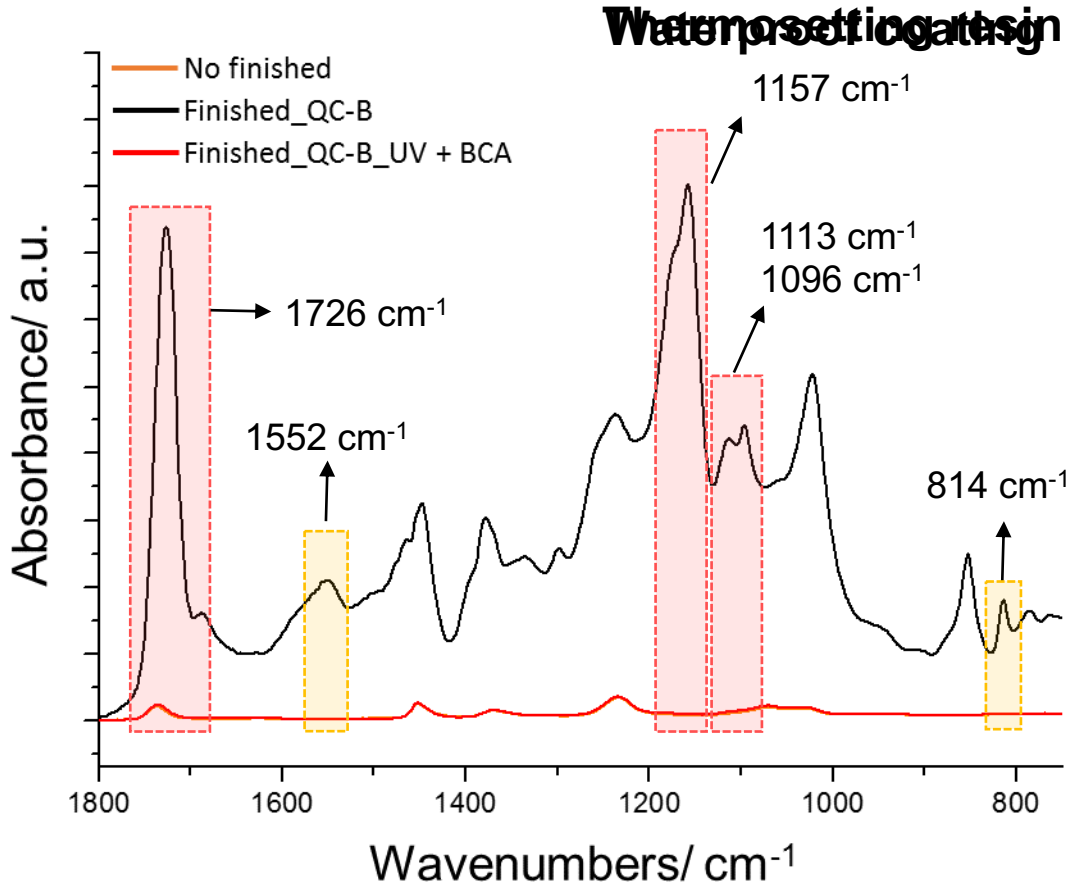
PRELIMINARY STUDIES ON QUALITY CONTROL FABRICS

ATR - FTIR characterization

Preliminary laboratory experiments have shown that the combination of the three chemical processes, supported by the photoirradiation of fabrics, is responsible for **over 90%*** removal of the applied finishing **"B"**.

*calculated on the basis of calibration lines

"B"

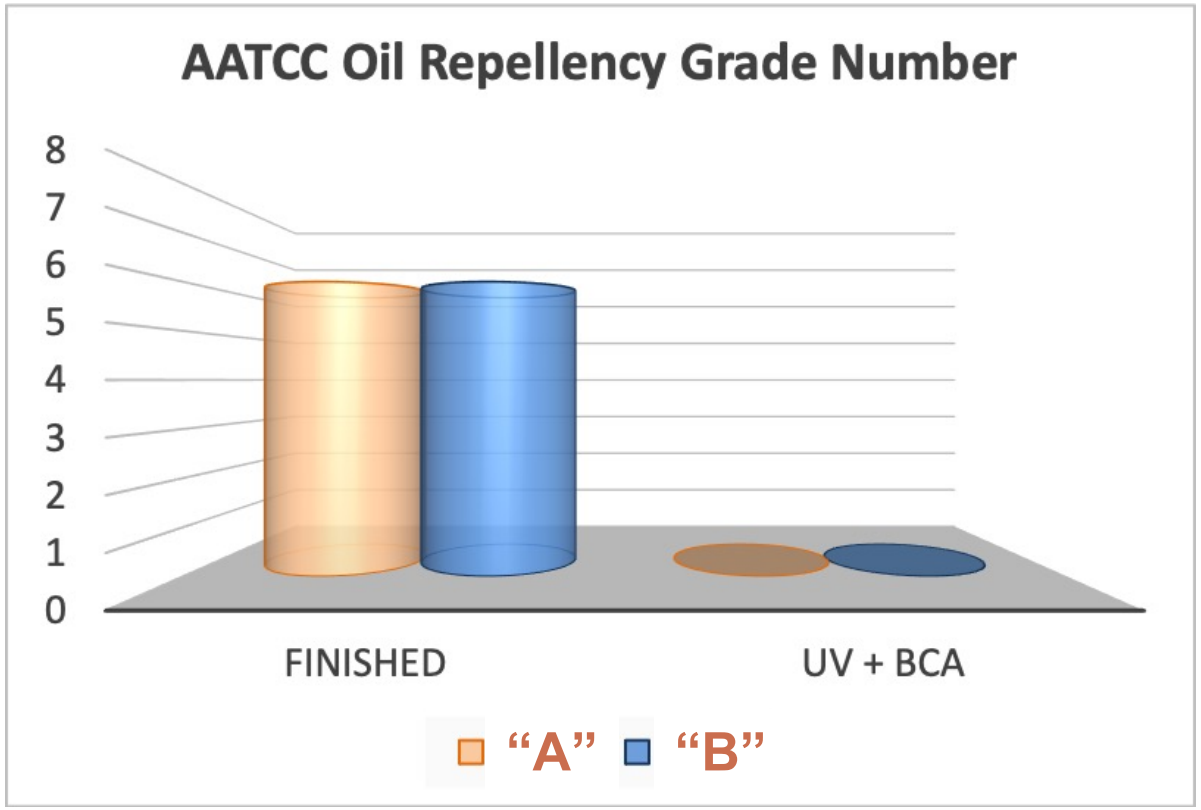


CONTAMINANTS REMOVAL FROM ACRYLIC FABRICS

PRELIMINARY STUDIES ON QUALITY CONTROL FABRICS

AATCC Test Method 118-2013: Oil repellency

This process led to excellent performance, in terms of wettability, of both fabrics, thus providing almost **"cleaned" acrylic fabrics to be re-used** for environmentally friendly finishing.



CONTAMINANTS REMOVAL FROM ACRYLIC FABRICS

PRELIMINARY STUDIES ON QUALITY CONTROL FABRICS

Perfluorocarbon extraction (UNI CEN/TS 15968:2010)

UV + BCA	6:2 FTOH
"A"	0.22 ppm
"B"	0.56 ppm

PFCs extraction data (< 1 ppm) confirmed the **efficacy** of the combination of dry and wet processes in the finishing removal from acrylic substrates.

CONTAMINANTS REMOVAL FROM ACRYLIC FABRICS

FINISHING REMOVAL FROM POST-CONSUMER FABRICS

The selected combination of treatments:

- ✓ **B** (acid hydrolysis)
- ✓ **BCA** (combination of acid/alkaline hydrolysis and chemical/mechanical washing)
- ✓ **UV + BCA** (combination of dry and wet processes)

were performed on two kinds of post-consumer acrylic fabrics:

"A"

THERMOSETTING RESIN
FLUOROCARBON RESIN

"B"

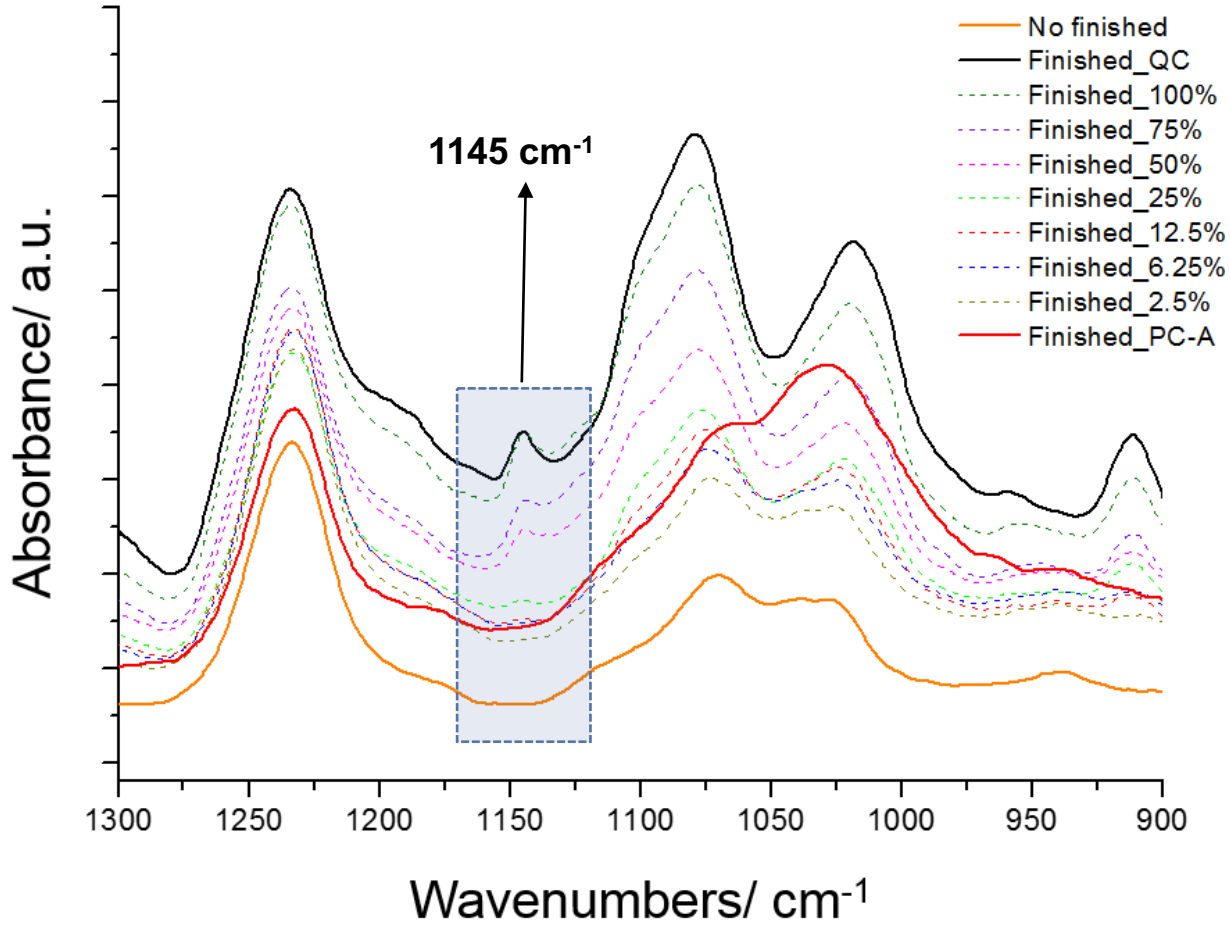
THERMOSETTING RESIN
FLUOROCARBON RESIN
WATERPROOF COATING

CONTAMINANTS REMOVAL FROM ACRYLIC FABRICS

FINISHING REMOVAL FROM POST-CONSUMER FABRICS

Comparing spectra of post-consumer **"A"** sample with those of **acrylic fabrics treated with different amounts of finishing**, it could **be estimated** that the **finishing** of this post-consumer awning is **between 6.25 and 2.5%** (fluorocarbon resin).

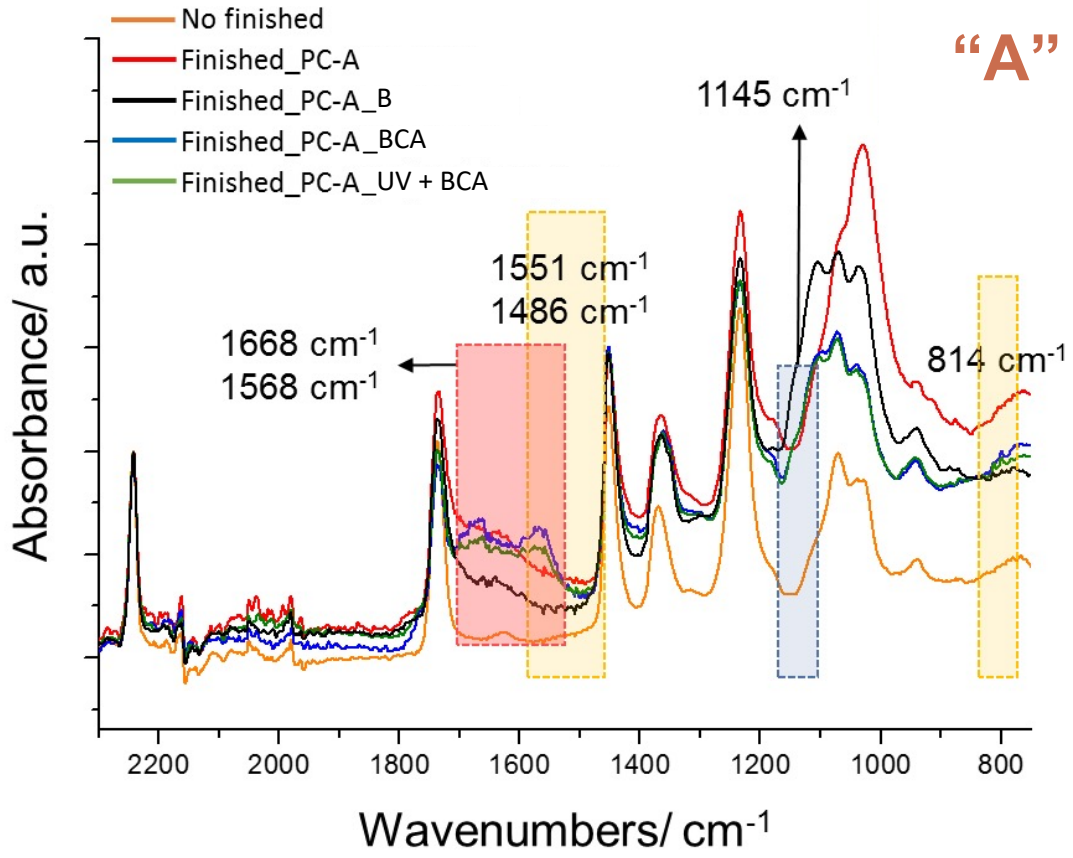
This finishing amount of waste acrylic can be the result of a **slight degradation process** over time of sunlight and atmospheric agents.



CONTAMINANTS REMOVAL FROM ACRYLIC FABRICS

FINISHING REMOVAL FROM POST-CONSUMER FABRICS

FTIR spectra of post-consumer fabrics showed that all the treatments performed on finished “A” samples provide a **certain reduction in the infrared curves of finishing**.

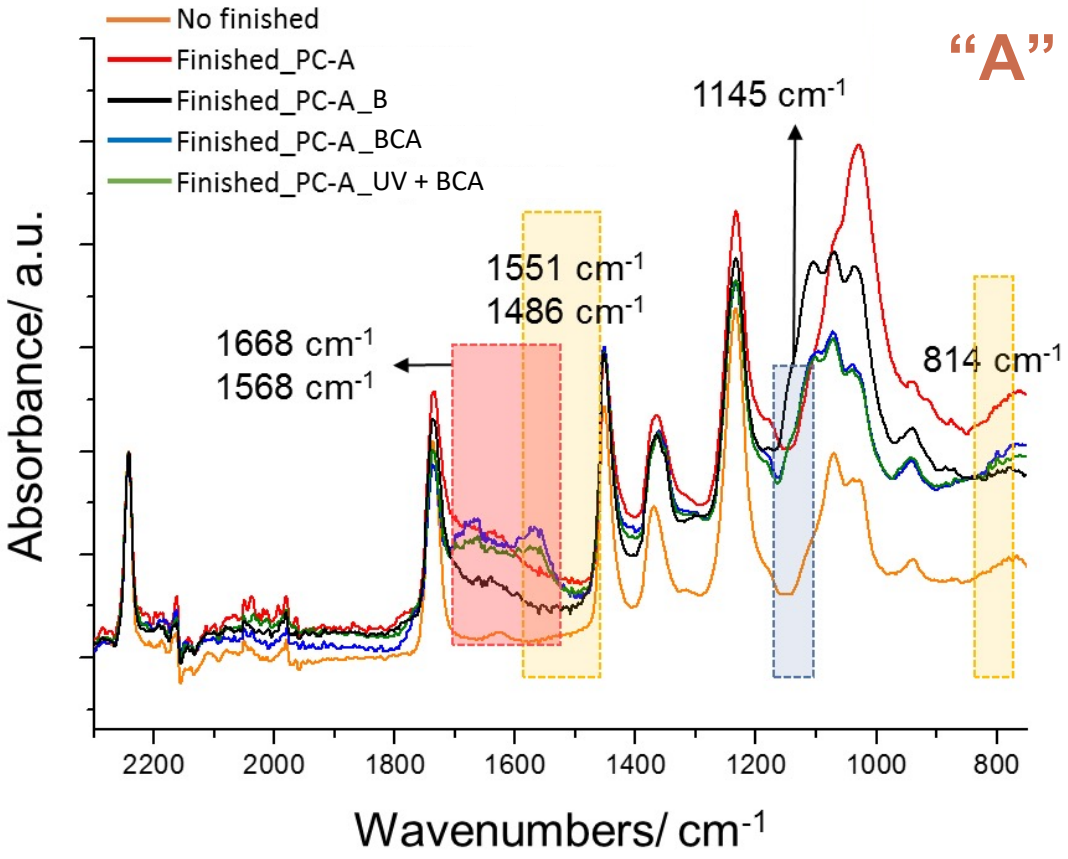


CONTAMINANTS REMOVAL FROM ACRYLIC FABRICS

FINISHING REMOVAL FROM POST-CONSUMER FABRICS

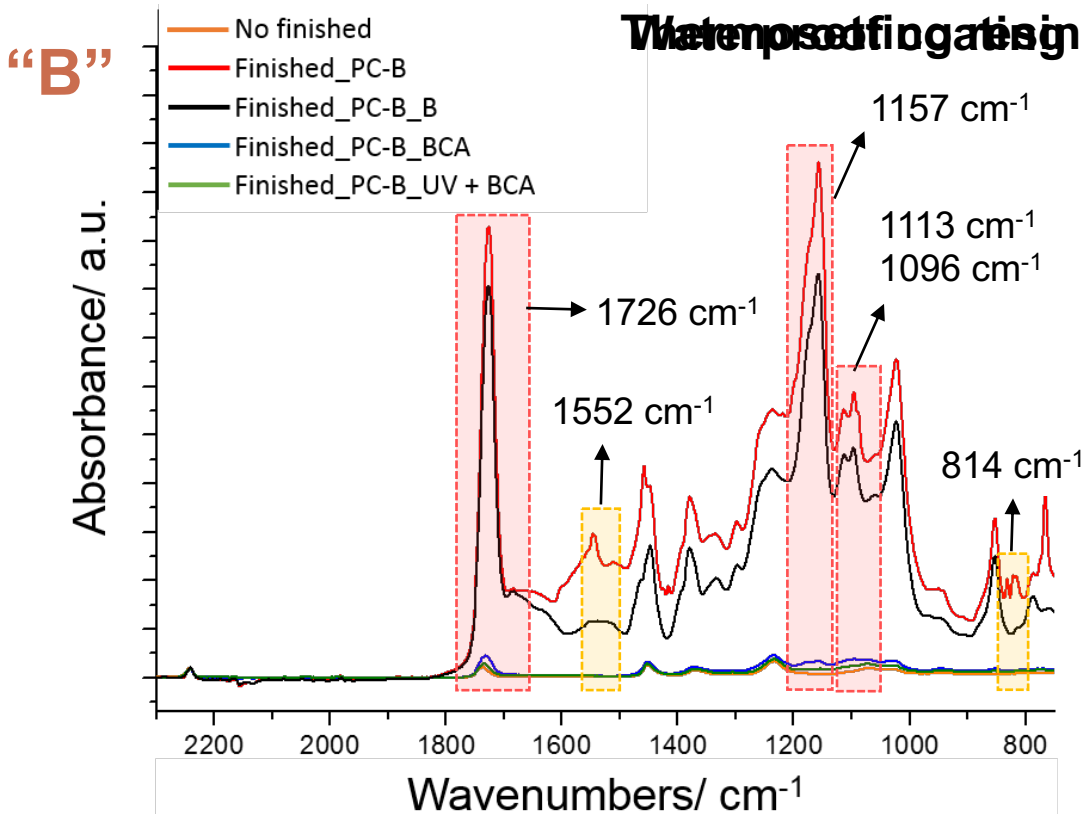
However, the combination of treatments evidenced the **appearance of broad peaks** in the region 1560 and 1670 cm^{-1} ascribable to slight changes in the chemical structure of acrylic fibres:

- aromatic C=N structures leading to **intramolecular cyclization**;
- conjugated structures (HC=N–N=CH) responsible for **intermolecular cross-linking**.



CONTAMINANTS REMOVAL FROM ACRYLIC FABRICS

FINISHING REMOVAL FROM POST-CONSUMER FABRICS



The singular acid hydrolysis was not efficient in the removal of finishing from fabric "B".

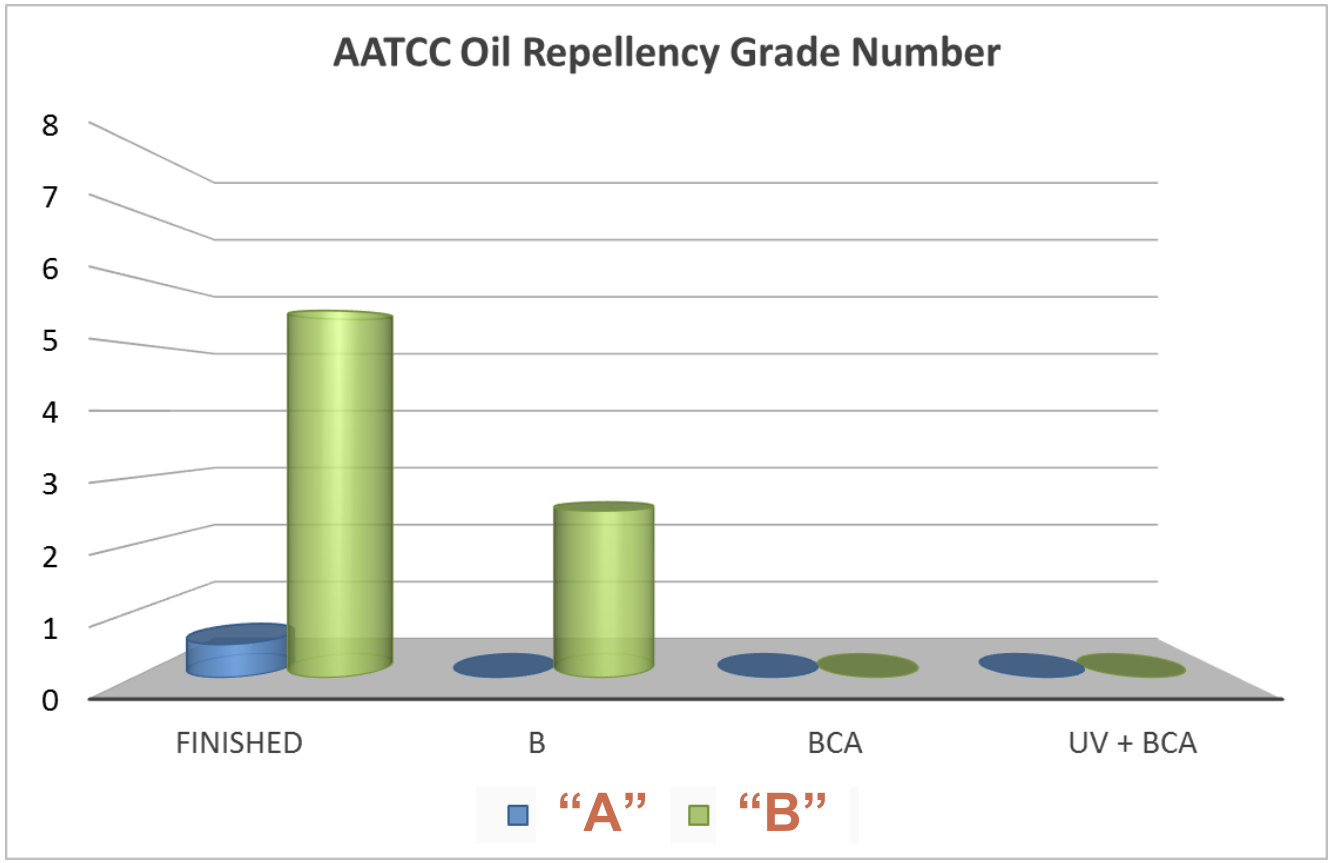
Both combined chemical treatments of fabrics **provided the removal of finishing** since the IR spectra of the so-treated samples are almost overlapped with no-finished acrylic fabric.

CONTAMINANTS REMOVAL FROM ACRYLIC FABRICS

FINISHING REMOVAL FROM POST-CONSUMER FABRICS

AATCC Test Method 118-2013: Oil repellency

As evident by the histogram, all performed treatments on both “A” and “B” post-consumer fabrics proved to be **efficient in removing finishing**, except the singular acid hydrolysis for "B" fabrics.



CONTAMINANTS REMOVAL FROM ACRYLIC FABRICS

FINISHING REMOVAL FROM POST-CONSUMER FABRICS

Perfluorocarbon extraction (UNI CEN/TS 15968:2010)

B	PFOA	PFDA	PFDoA	PFTeA
"A"	< LOD	< LOD	< LOD	< LOD
"B"	< LOD	< LOD	< LOD	< LOD

BCA	PFOA	PFDA	PFDoA	PFTeA
"A"	< LOD	< LOD	< LOD	< LOD
"B"	< LOD	< LOD	< LOD	< LOD

UV + BCA	PFOA	PFDA	PFDoA	PFTeA
"A"	< LOD	< LOD	< LOD	< LOD
"B"	< LOD	< LOD	< LOD	< LOD

The not detectable PFCs values obtained for "A" and "B" samples treated with all the combined chemical treatments and dry conditions confirmed the efficacy of the removal processes, which led to **"cleaned" acrylic fabrics** for a "second life".

CONCLUSIONS

- ✓ A new process for **hazardous chemicals removal** from finished acrylic textiles, with **innovative investigation and processing techniques** was developed to obtain a **fully compatible recycled acrylic textile for reuse;**

- ✓ The combination of both chemical treatments and photodegradation process of post-consumer fabrics reveals the **total removal of both finishing,** thus obtaining **cleaned fabrics** for a "second life" to be used with environmentally friendly finishing.

CONCLUSIONS

The excellent results obtained suggest several **impacts expected** concerning:

- ✓ Increased **recycling rate** and reduced landfill and incineration;
- ✓ Reduced risk of retaining **hazardous substances** in recycled materials;
- ✓ Promotion of the **Technology transfer** to other sectors;
- ✓ **New market** opportunities;
- ✓ **Social impact** (growing sustainability awareness).

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THANKS FOR YOUR ATTENTION

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