REACT Webinar: Removing Harmful Chemicals from Textile Waste

Removing chemicals from post-consumer outdoor textiles

EU GREEN WEEK 2021 PARTNER EVENT

ZERO POLLUTION #EUGreenWeek

for healthier people and planet

REACT

Removing chemicals from post-consumer outdoor textiles

The REACT project aims to the **management of waste acrylic textiles** coming from **outdoor awnings and furnishing**.

The overall aim of the proposal is to develop a **method to remove hazardous** finishing substances from the waste of acrylic fabrics to **improve their recycling** for a "second life“.

Removing chemicals from post-consumer outdoor textiles

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).

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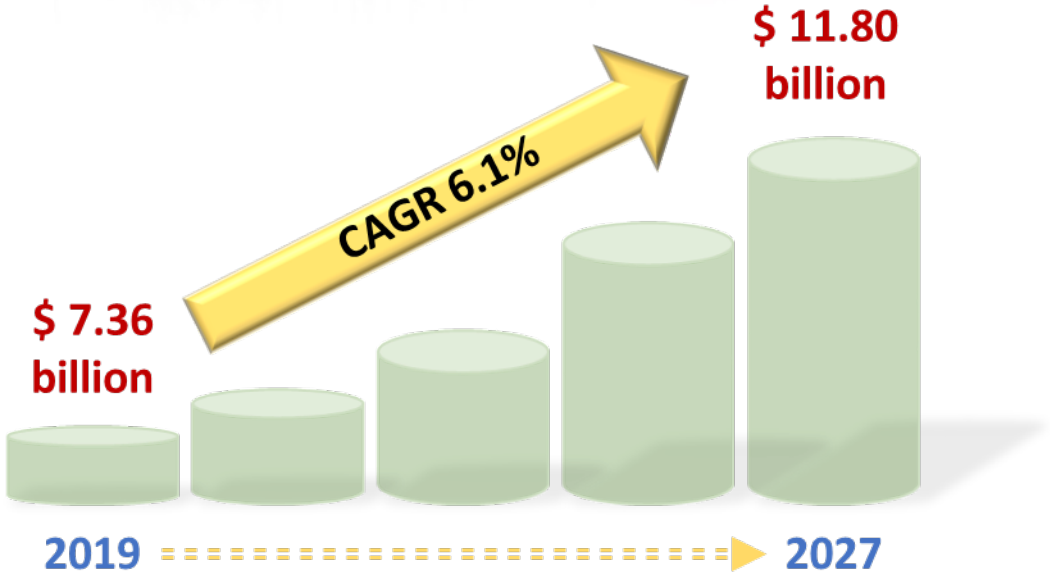
Global Awning Market 2020 - 2027

The management of post-consumer awnings and outdoor textiles has become **of great relevance during last years** by considering the Global Market size.

The forecast of this portion market up to 2027 **suggests an ever-growing interest in the sustainable disposal of this "waste"** not only for the fabric itself but also in terms of environmental safety due to the finishing applied for the best performance.



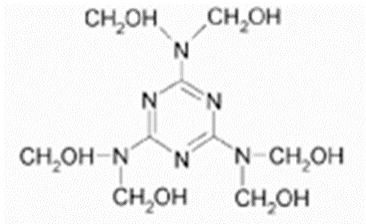
https://www.verifiedmarketresearch.com/product/awning-market/

Removing chemicals from post-consumer outdoor textiles

Chemical finishes for outdoor applications

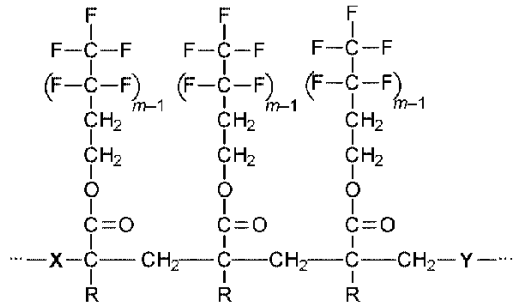
For outdoor applications, the commonly used synthetic fabrics are **finished with specific chemicals** to increase their resistance to atmospheric agents and make them long-lasting water-resistant.

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



Melamine-formaldehyde resins

Acrylic resins



Perfluorocarbon resins (PFC)

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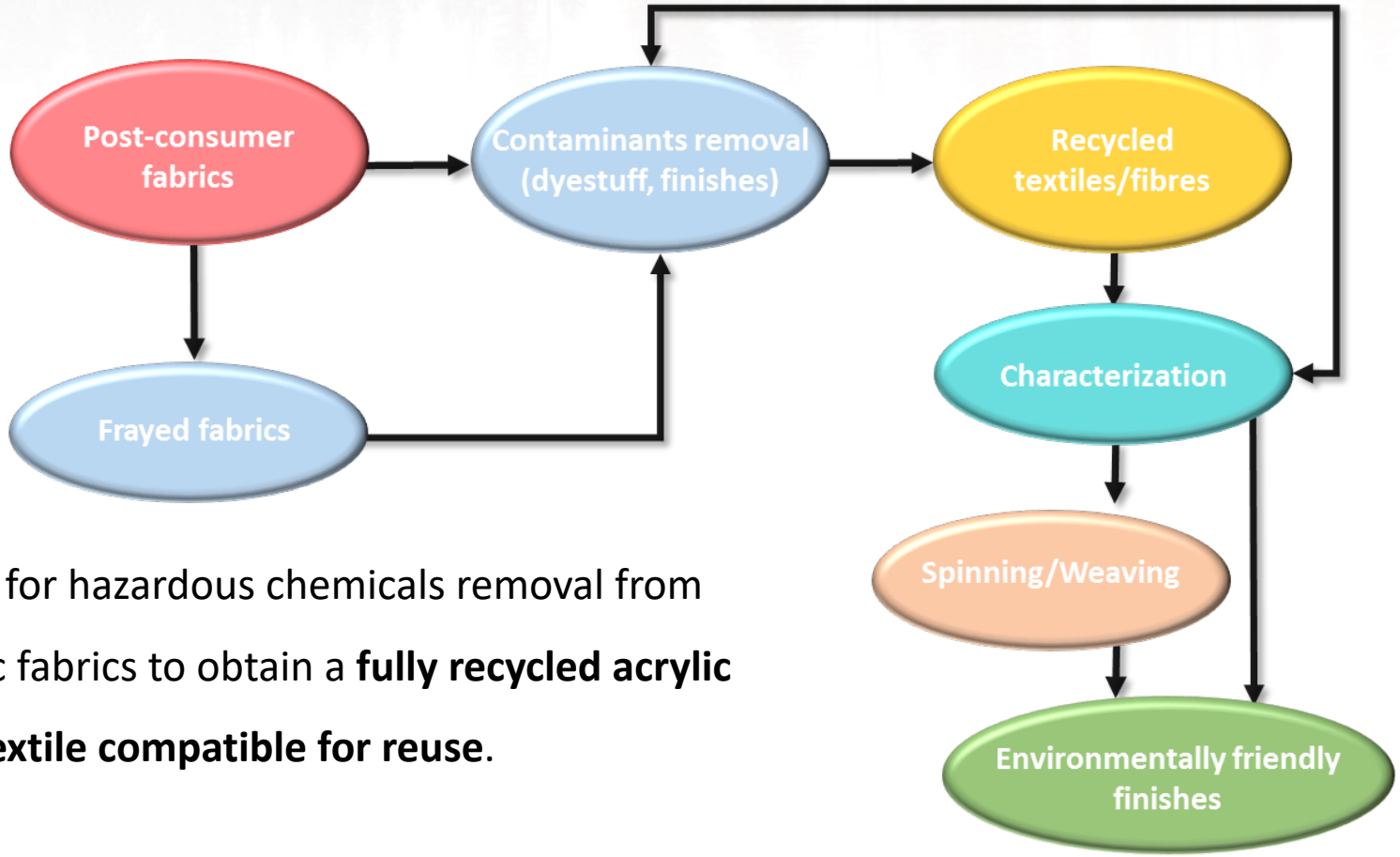
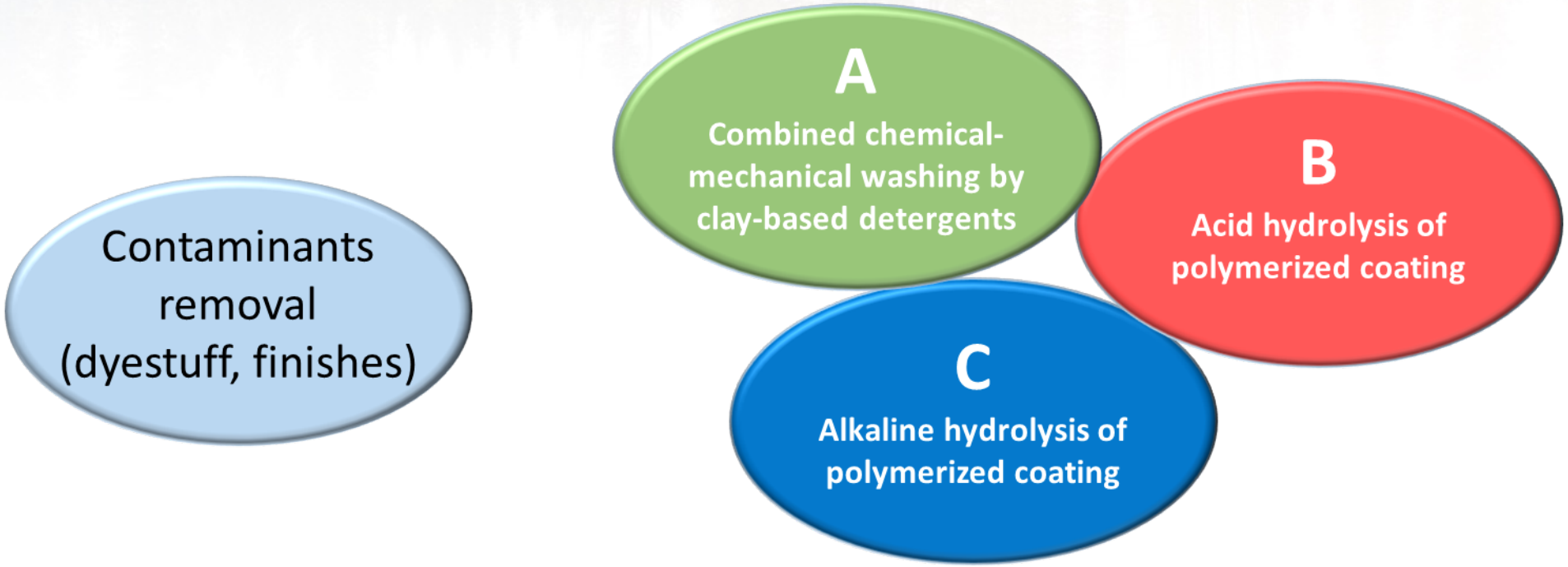
How to remove hazardous chemicals from post-consumer acrylic fabrics for a “second life”



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

Removing chemicals from post-consumer outdoor textiles

How to remove hazardous chemicals from post-consumer acrylic fabrics for a “second life”: chemical approach



To remove resins, fluorocarbon coatings, anti-mold product, melamine and acrylic binders, **chemical attacks** were investigated, involving wetting and dispersing agents, studying the pH influence.

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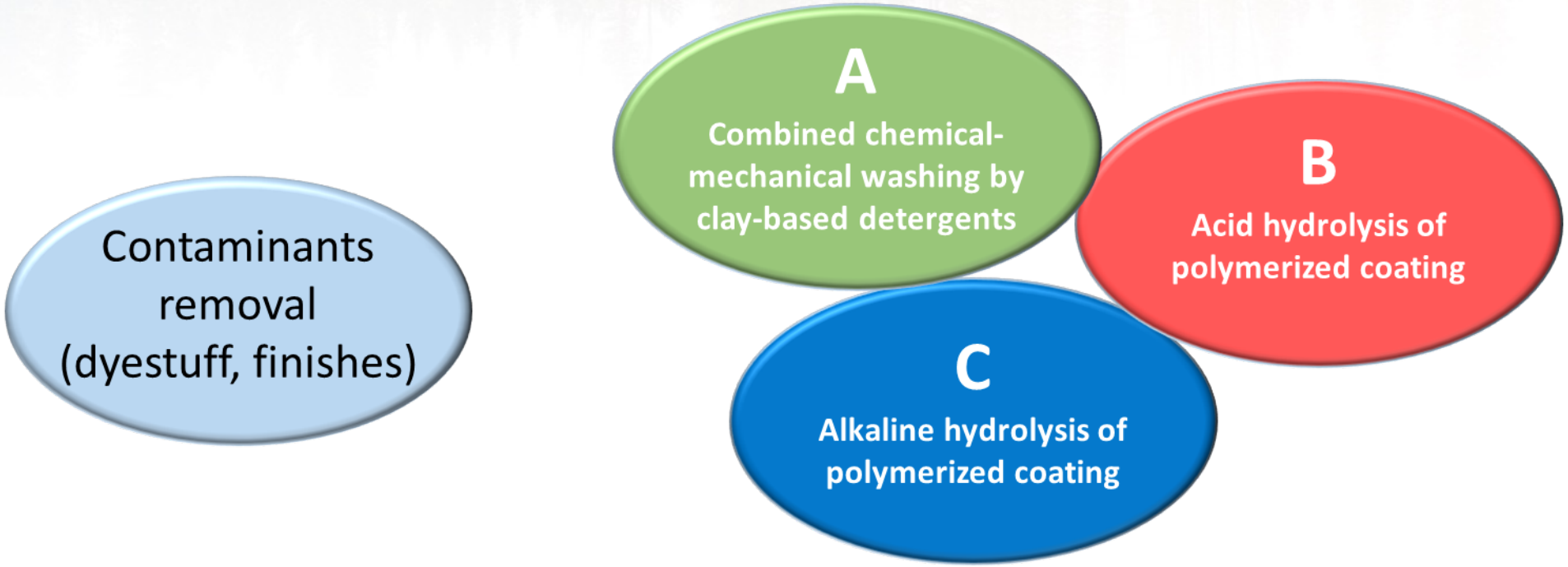
How to remove hazardous chemicals from post-consumer acrylic fabrics for a “second life”: chemical approach



The removal finishing procedure is a combination of chemical attacks under wet (A, B, C treatments) and dry conditions (photodegradation).

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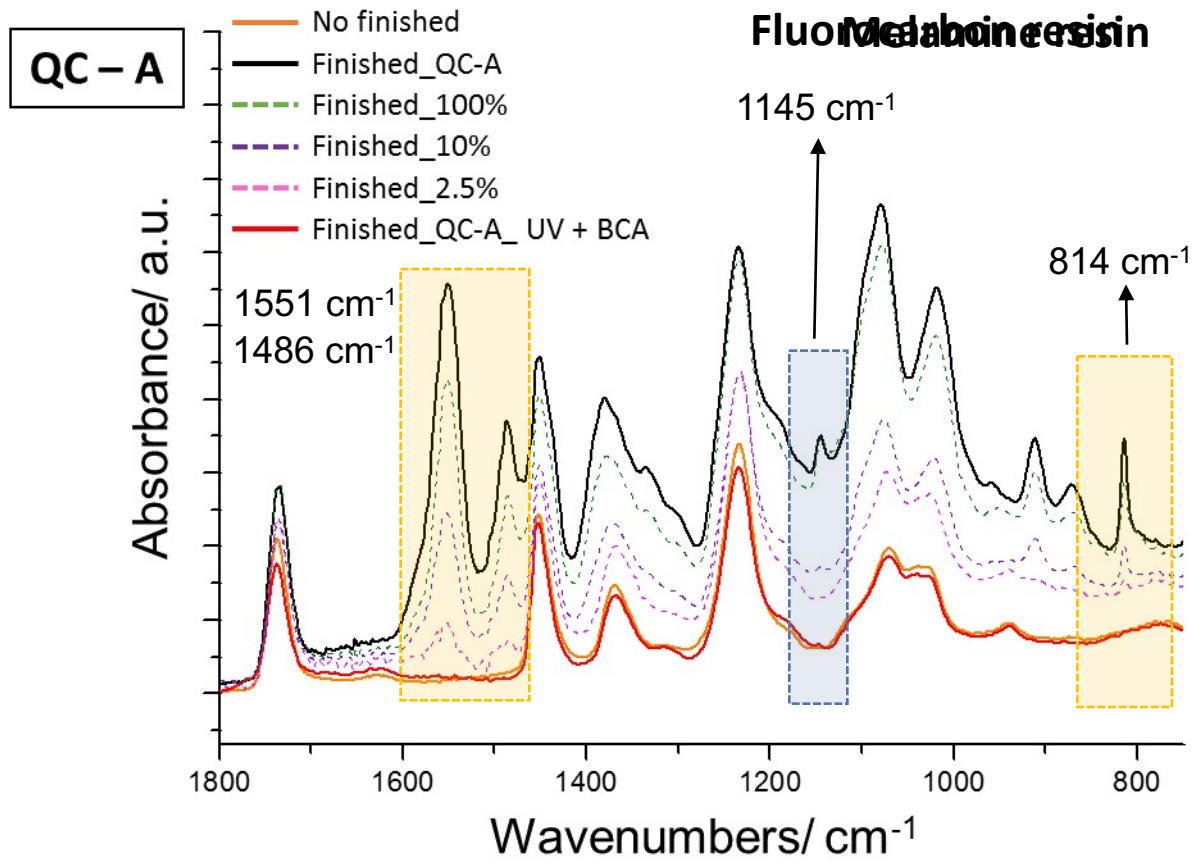
Contaminants removal from acrylic fabrics for outdoors applications: Preliminary studies on quality control fabrics (QC)

Preliminary laboratory experiments have shown that the combination of the three chemical processes, supported by the photoirradiation of fabrics, is responsible for **over 80%*** removal of the applied finishing (both **QC – A** and **QC – B**).

*calculated on the basis of calibration lines



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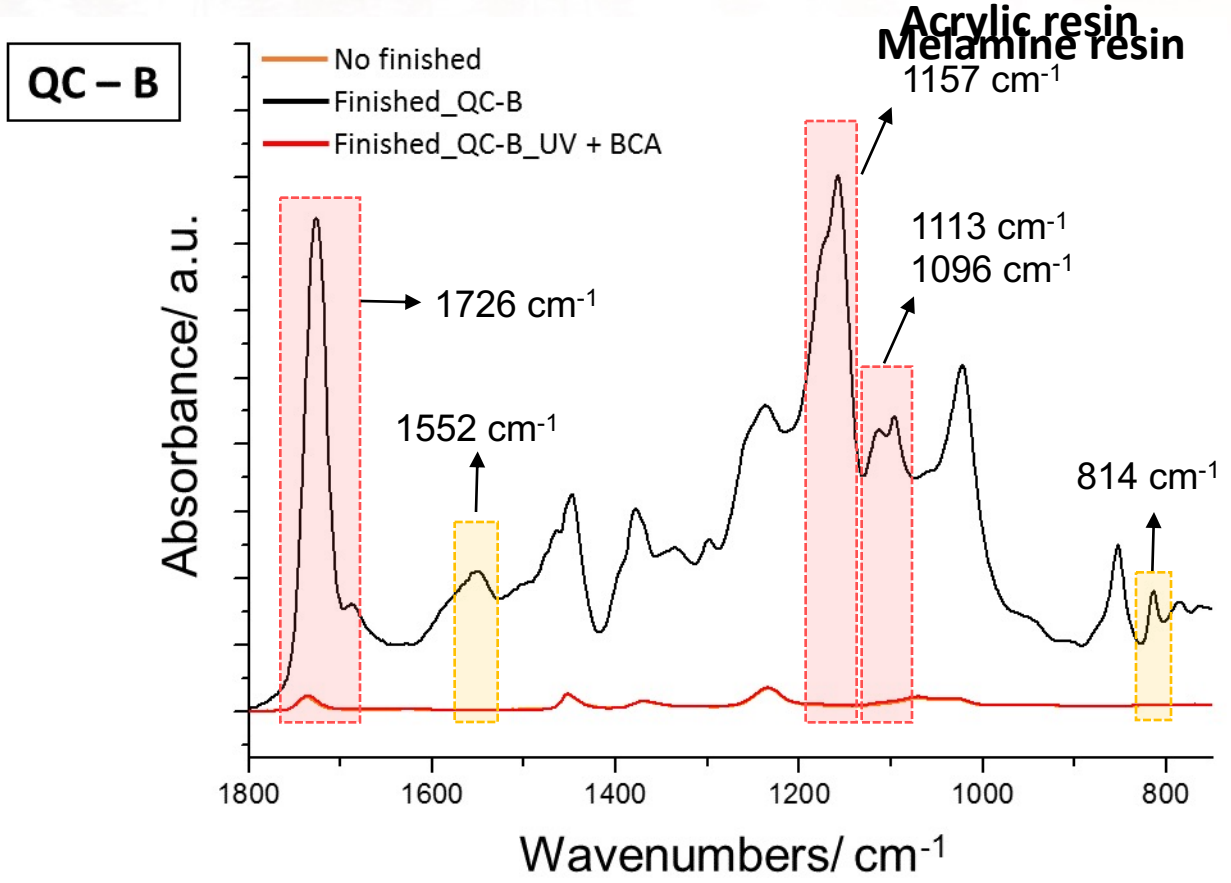

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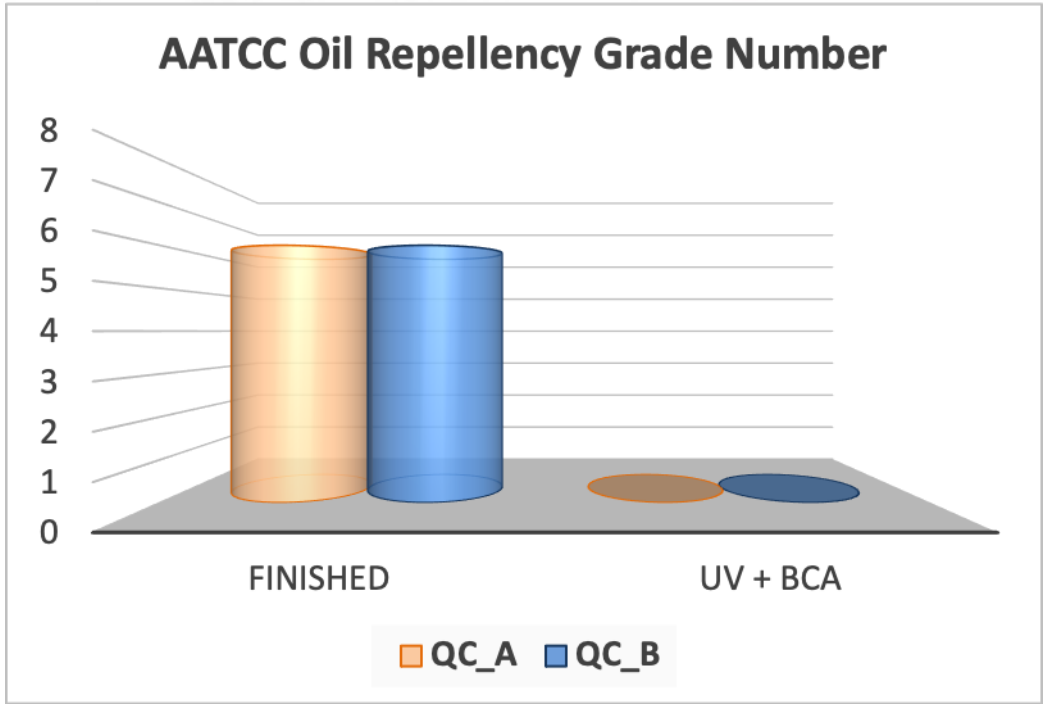
Contaminants removal from acrylic fabrics for outdoors applications: Preliminary studies on quality control fabrics (QC)

AATCC Test Method 118-2002: 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.



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Finishing removal strategy on post-consumer fabrics (PC)

The selected combination of treatments:

- **B** (acid hydrolysis)
- **BCA** (combination of acid/alkaline hydrolysis and clay-based detergent washing)
- **UV + BCA** (combination of dry and wet processes)

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

PC-A and **PC-B**

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Finishing removal strategy on post-consumer fabrics (PC) and characterization of samples

Characterization of samples were performed on both finished and finished fabrics after the removal treatments according to:

- ATR-FTIR characterization
- AATCC Test Method 118-2002
- Perfluorocarbon extraction (UNI CEN/TS 15968:2010)

To assess the **chemical composition** of the finished fabrics before removal treatments and the **efficacy of the finishing removal processes**.

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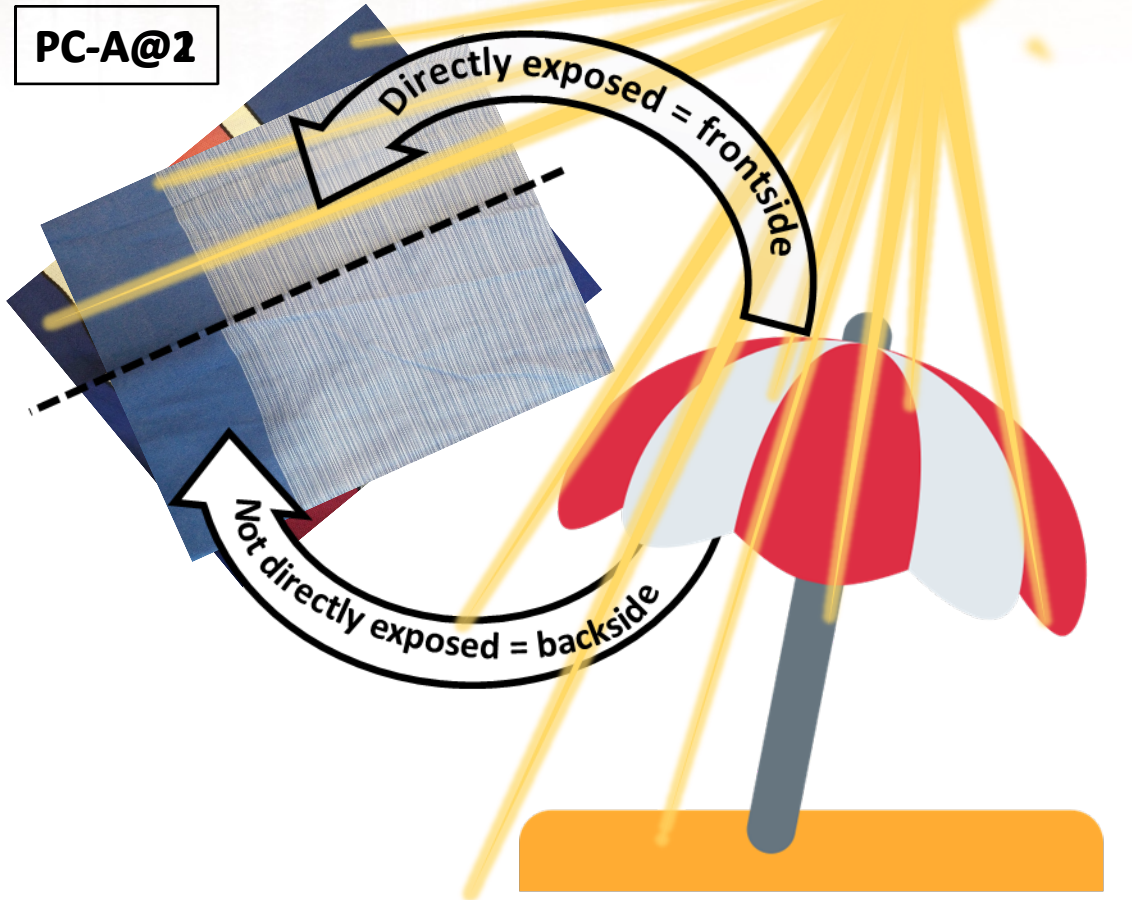
Finishing removal strategy on post-consumer fabrics "A" (PC-A@1 and PC-A@2): FTIR characterization of finished fabrics and influence of sunlight exposure

Prolonged exposure to sunlight and atmospheric agents resulted in an **expected slight yellowing** of the exposed side of the fabrics (frontside).

FTIR characterizations were carried out both on the sunlight directly/not directly exposed side of the fabric (frontside and backside, respectively) to investigate the effects of the different sunlight exposure over time.



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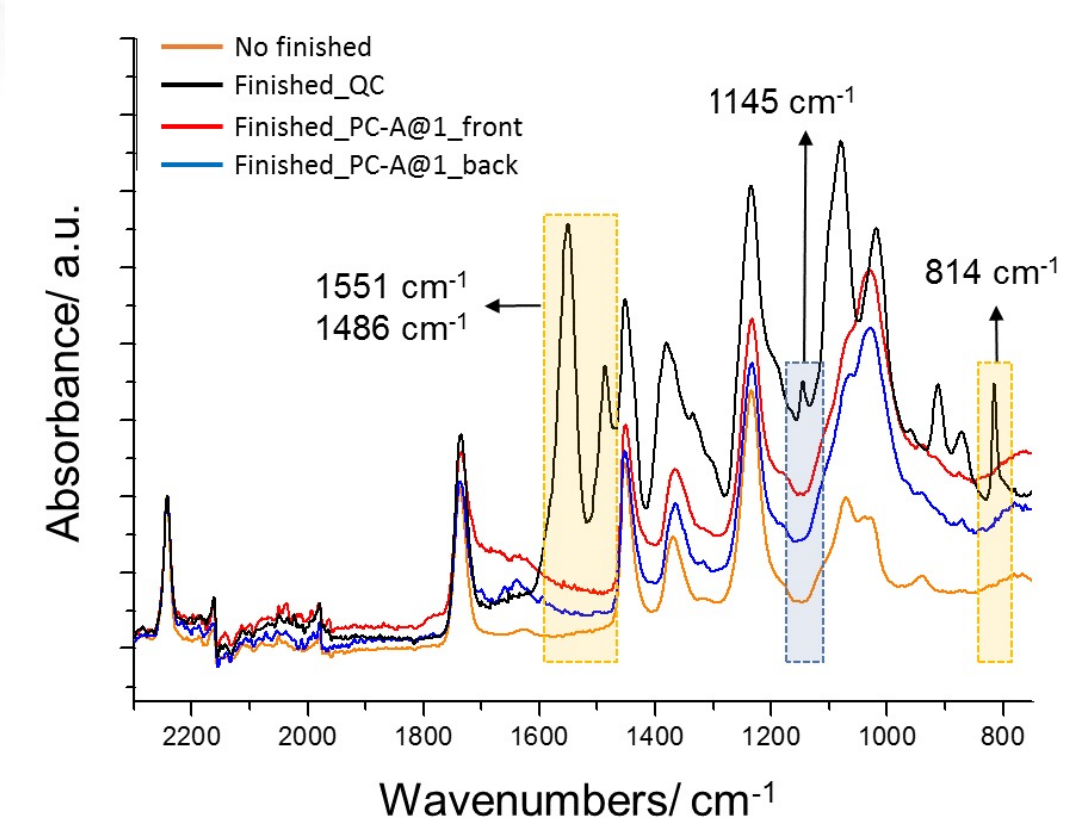
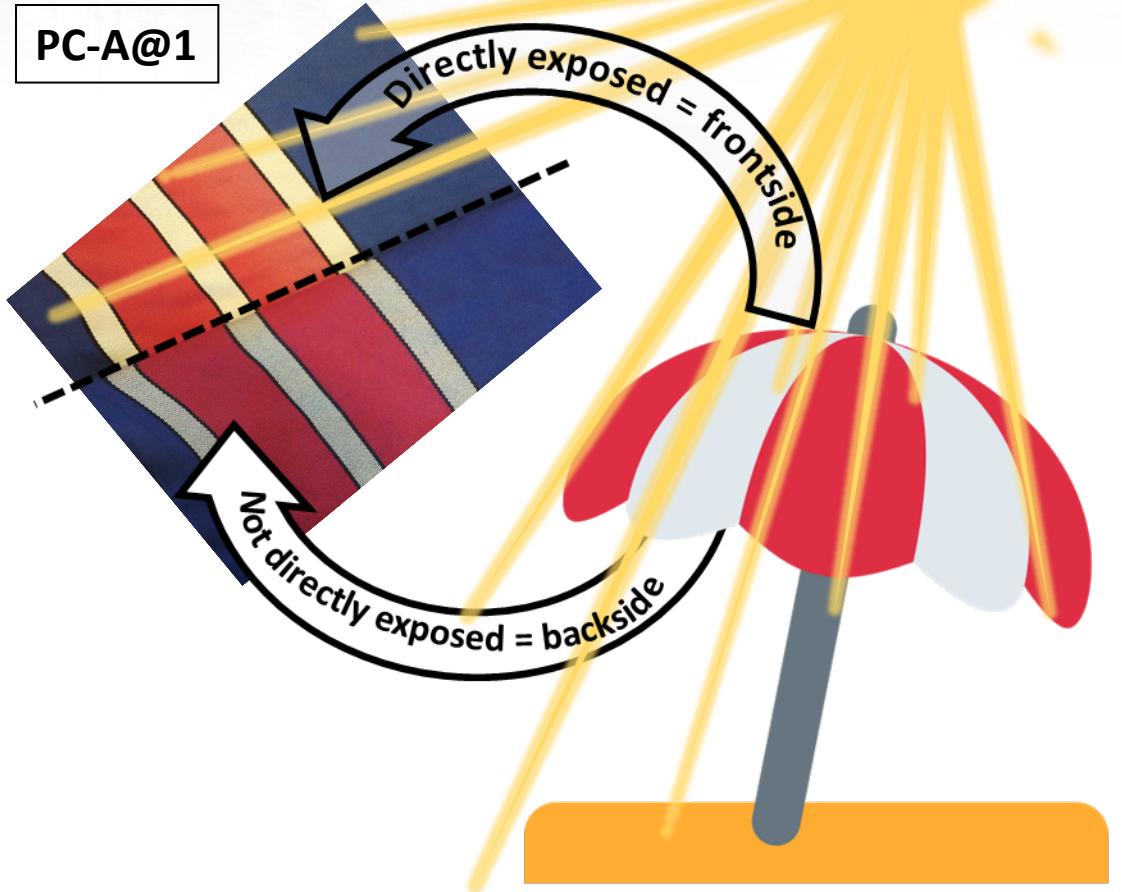
Finishing removal strategy on post-consumer fabrics "A" (PC-A@1):
FTIR characterization of finished fabrics and influence of sunlight exposure





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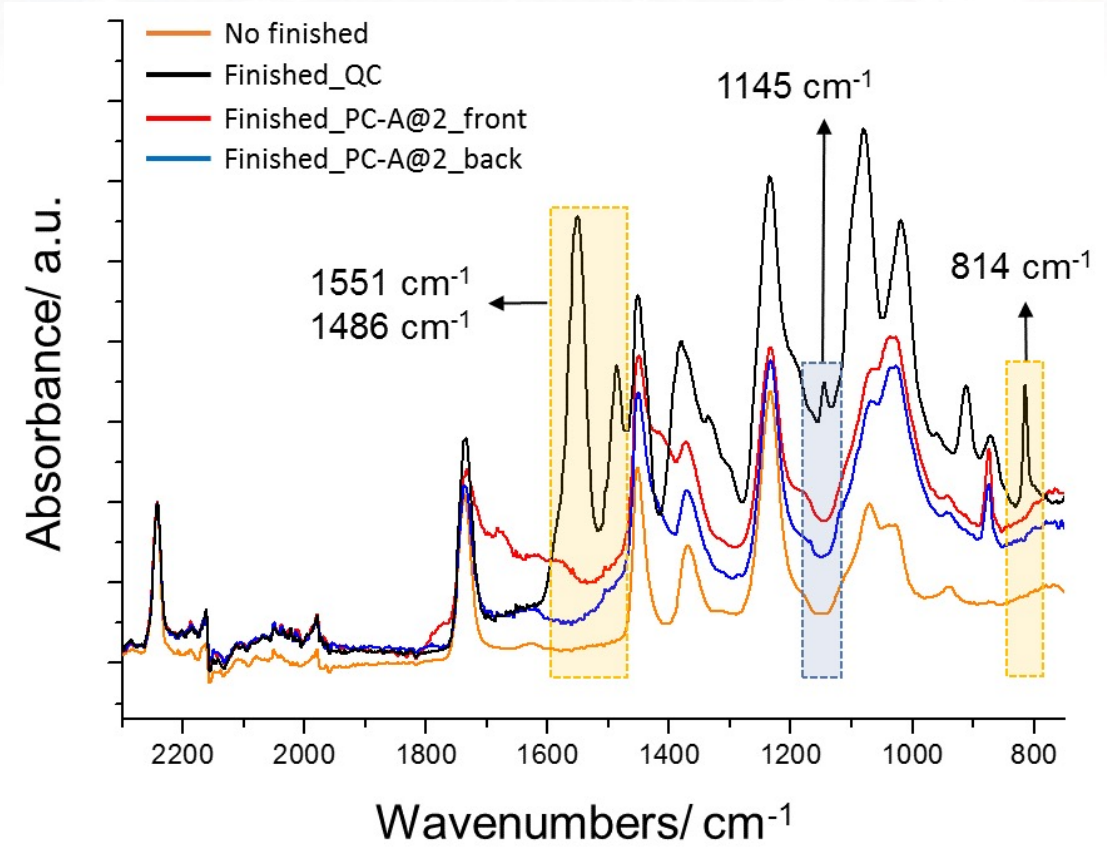
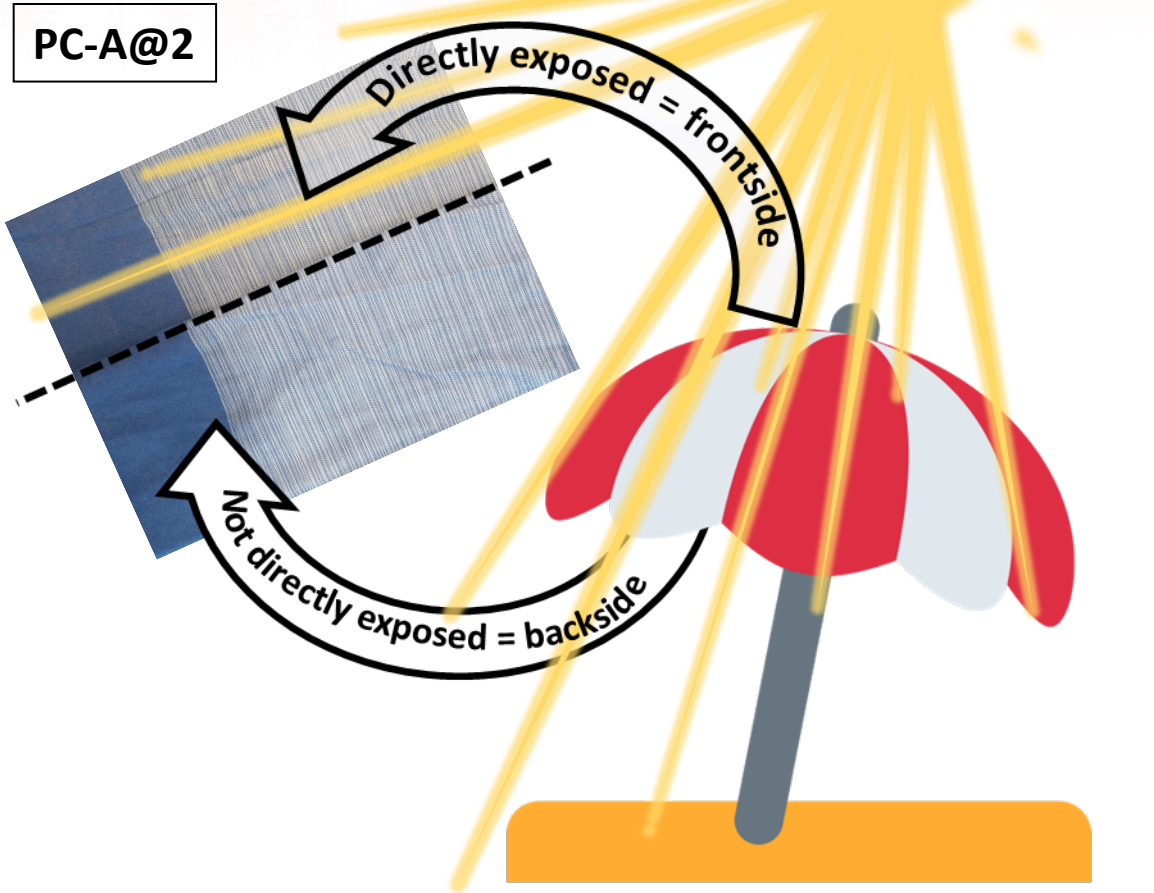
Finishing removal strategy on post-consumer fabrics "A" (PC-A@2):
FTIR characterization of finished fabrics and influence of sunlight exposure





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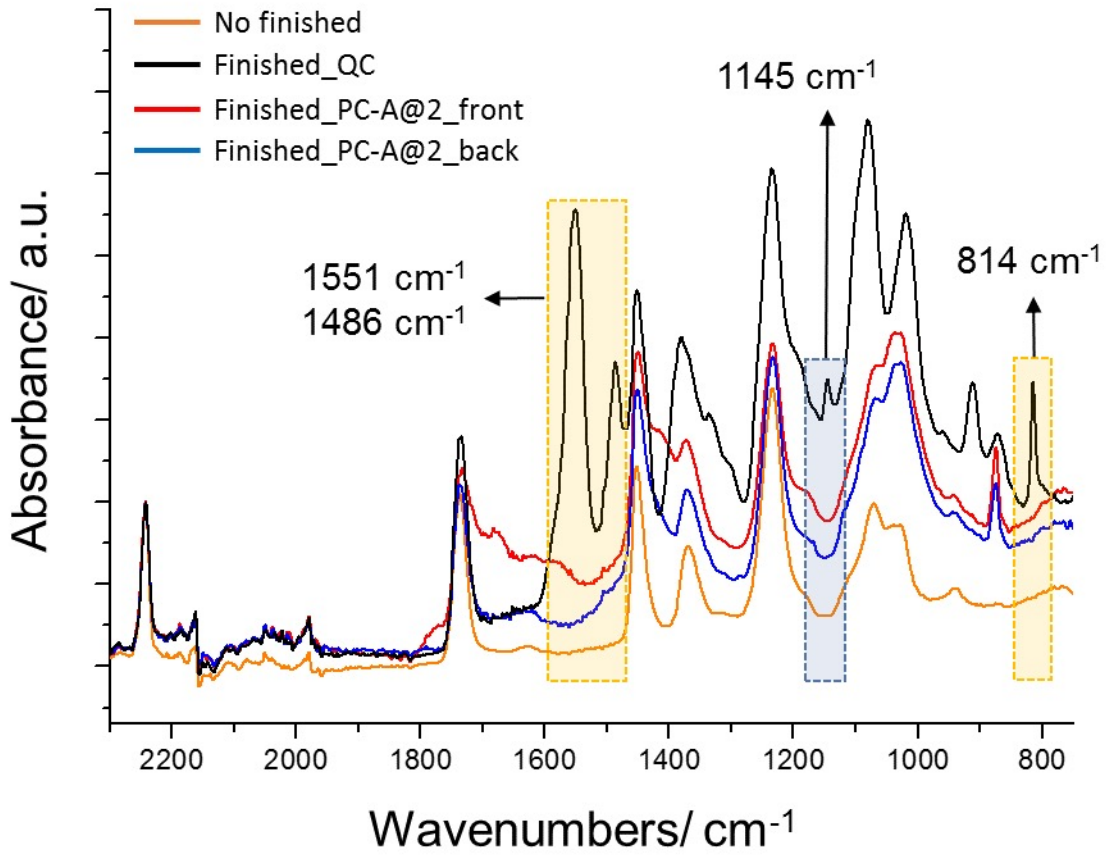
Finishing removal strategy on post-consumer fabrics "A" (PC-A@2):
FTIR characterization of finished fabrics and influence of sunlight exposure



As evident, the sunlight exposed side of the fabric has different characteristics than the no-exposed side due to a normal and **slight degradation over time** of the finishing applied and of the polymer itself.

In both cases, however, it is possible to note that the characteristic peaks of the finishing are **not discernable**, contrary to fabrics never exposed to the sunlight coming from the "quality control".

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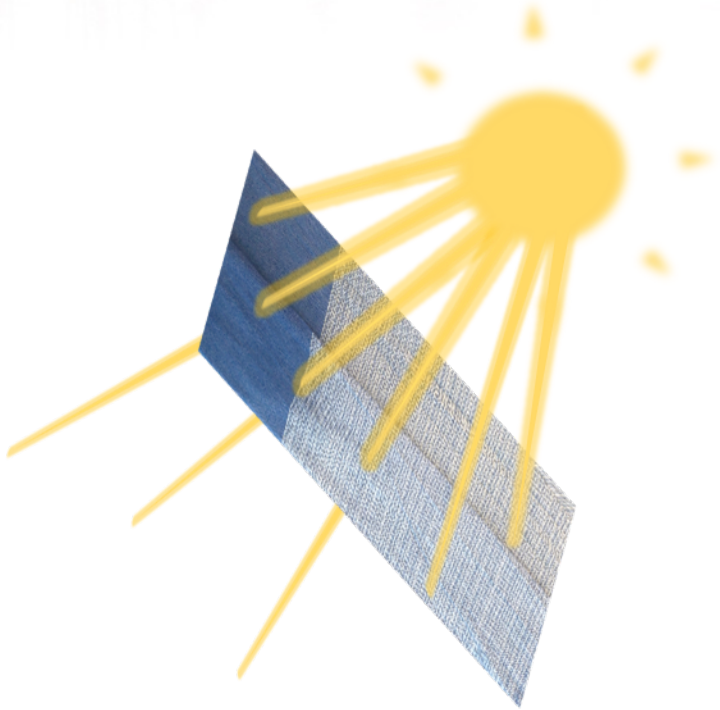
Influence of sunlight exposure on polymer fabrics

High temperature	→	Thermal Degradation
Oxygen, ozone, chemicals	→	Chemical Degradation
Electromagnetic (γ, UV)	→	Light induced Degradation
Moisture	→	Hydrolysis



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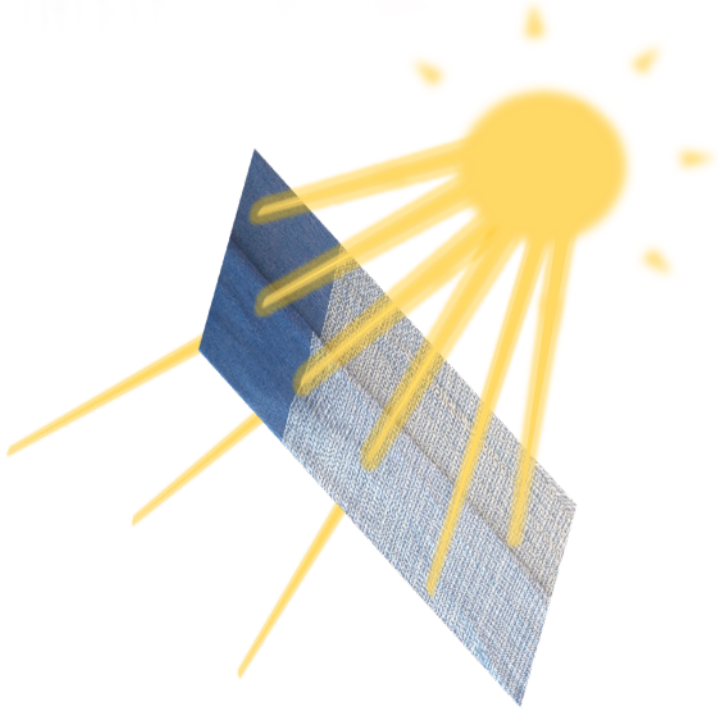
Influence of sunlight exposure on polymer fabrics

The absorption of UV-Vis light by the polymer results in chains scission and/or crosslinking.

- Changes in chemical structure
- Embrittlement
- Changes on surface
- Loss in mechanical properties



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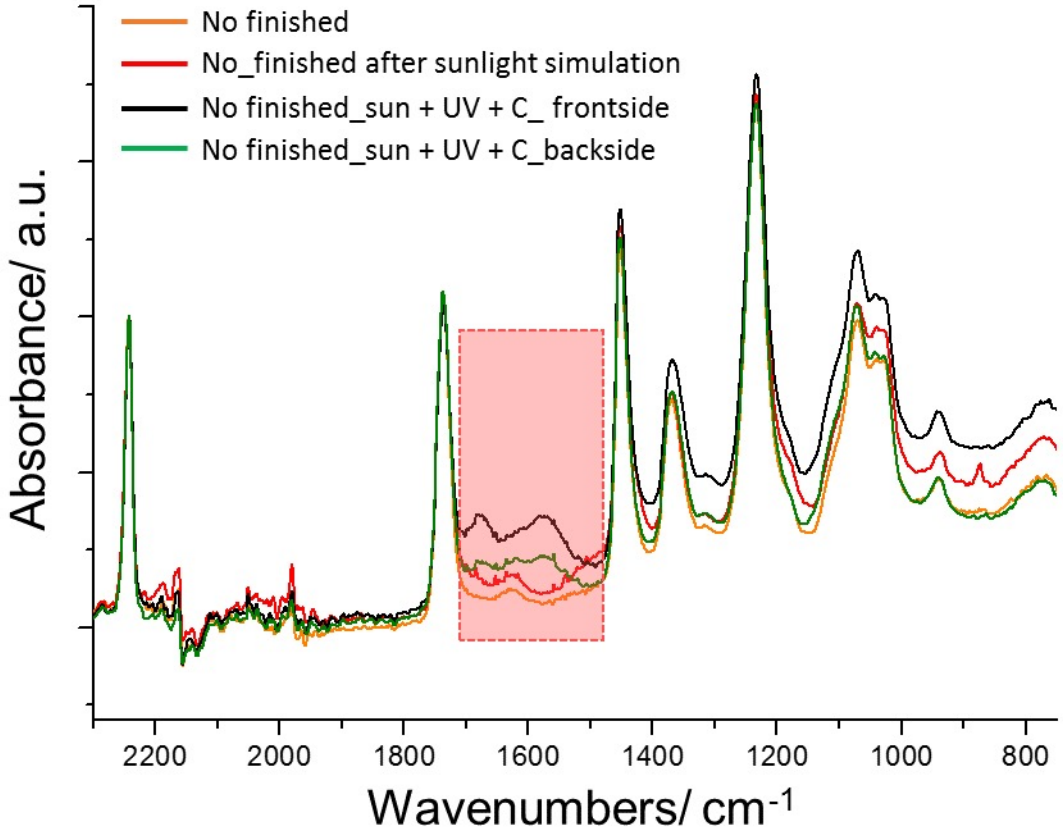
Simulation of sunlight exposure and removal treatments on no-finished and finished acrylic fabrics

The combination of treatments (both wet and dry conditions) evidenced the **appearance of broad peaks** in the region 1560 and 1670 cm^{-1} assigned to the formation of:

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



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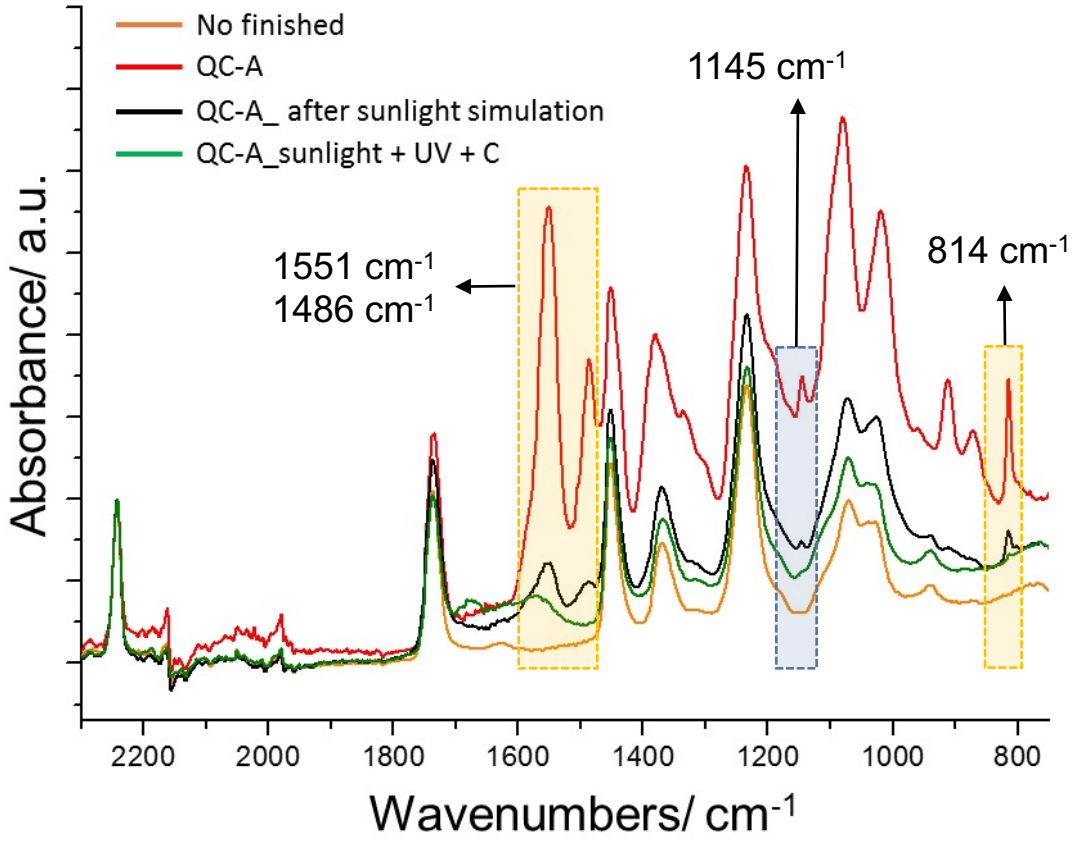
Simulation of sunlight exposure and removal treatments on no-finished and finished acrylic fabrics

The UV irradiation of finished “A” fabrics to simulate the sunlight exposure led to a **strong reduction** of the main infrared peaks characteristic of the finishing, thus **confirming its partial leaching**.



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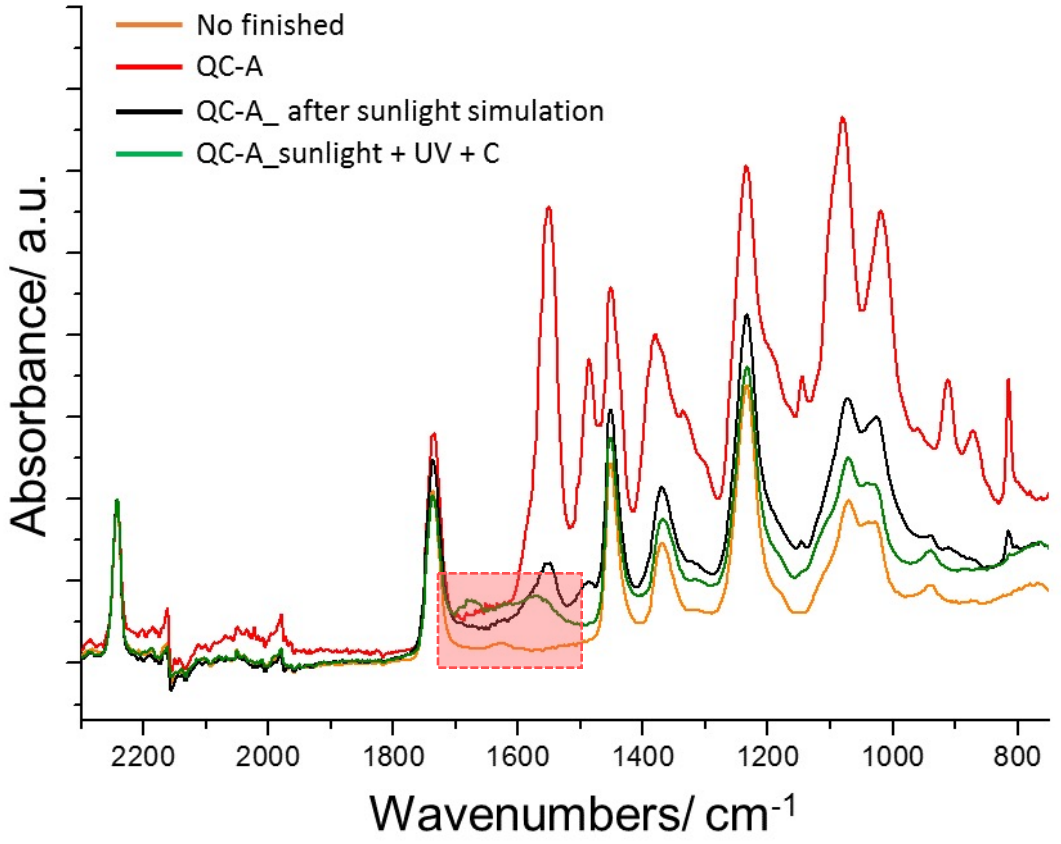

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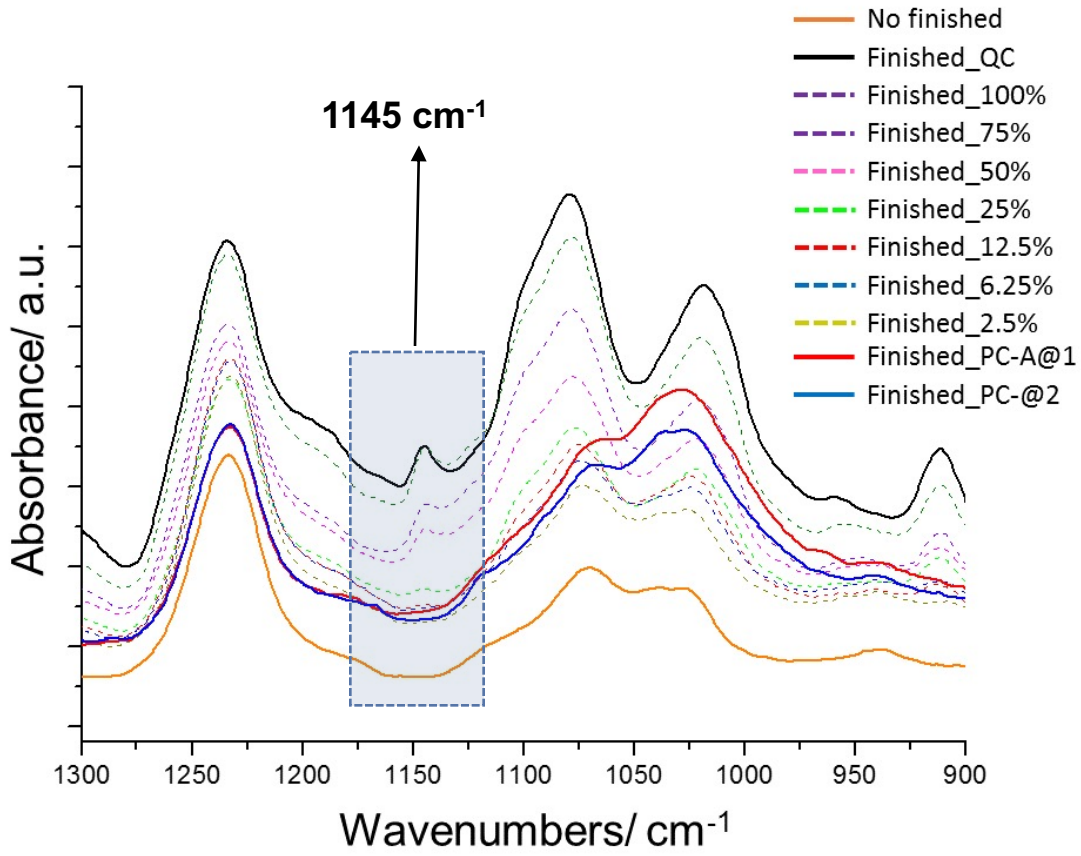
Finishing removal strategy on post-consumer fabrics "A" (PC-A@1 and PC-A@2): FTIR characterization of finished fabrics

However, for both investigated PC_A fabrics, the presence of the finishing is confirmed by the increased intensity of the infrared curves of fabrics with respect to a no-finished fabric. Comparing such spectra with those of **acrylic fabrics treated with different amount of finishing**, it could **be estimated** that the **residual finishing** of this post-consumer awning is **between 6.25 and 2.5%** (fluorocarbon resin).



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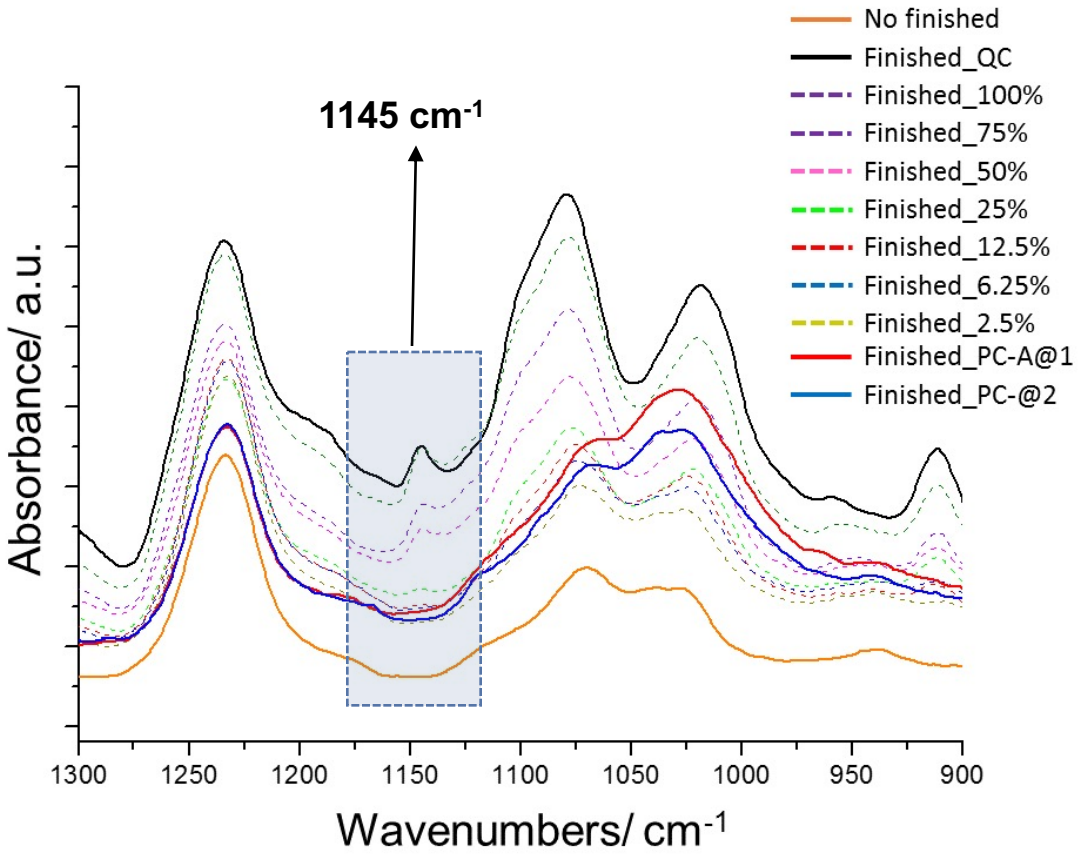
Finishing removal strategy on post-consumer fabrics "A" (PC-A@1 and PC-A@2): FTIR characterization of finished fabrics

This confirms the **finishing degradation** due to sunlight and atmospheric agents saw in the simulation experiments, which, over time, lead to the partial leaching of the finishing itself from fabrics.



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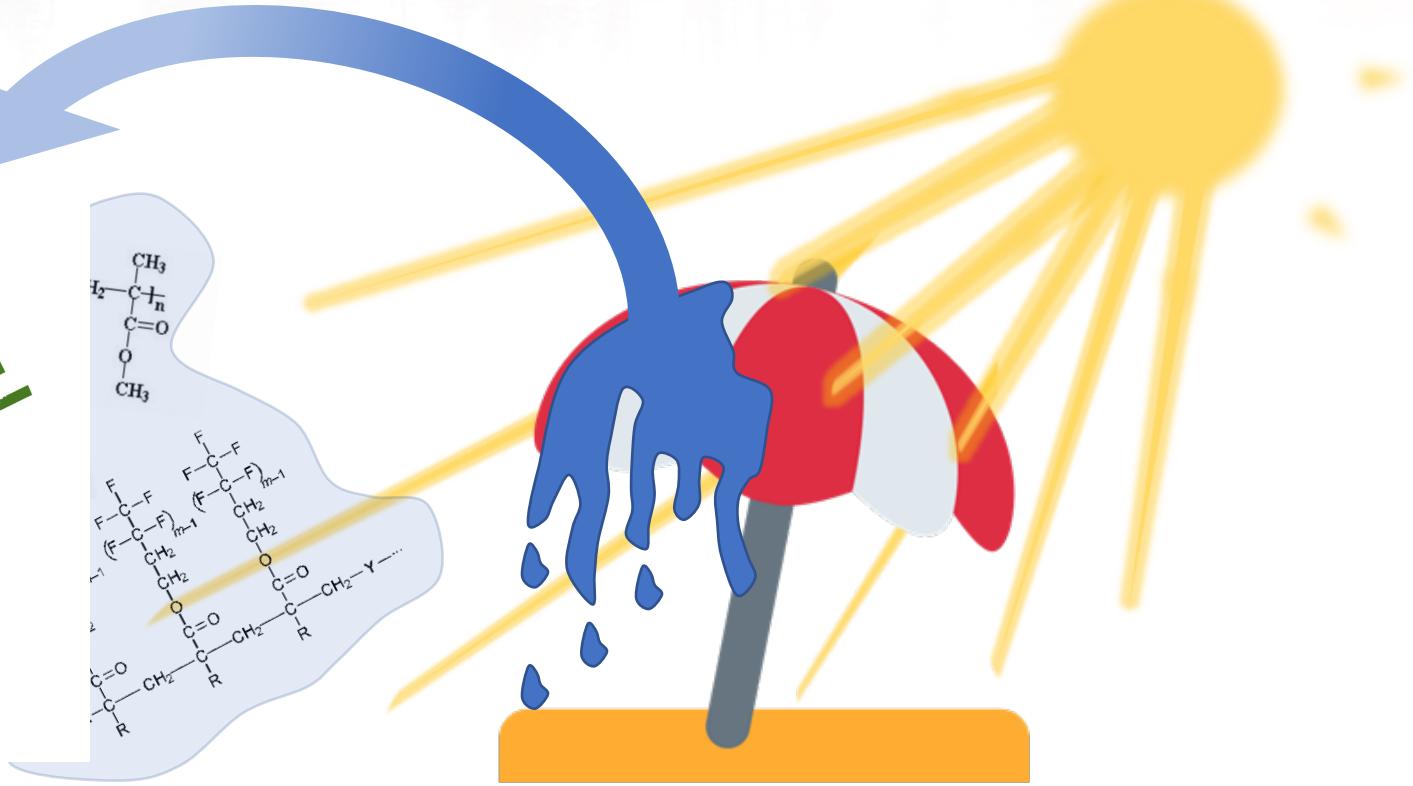
Influence of sunlight exposure on finishing applied onto fabrics: environmental issue



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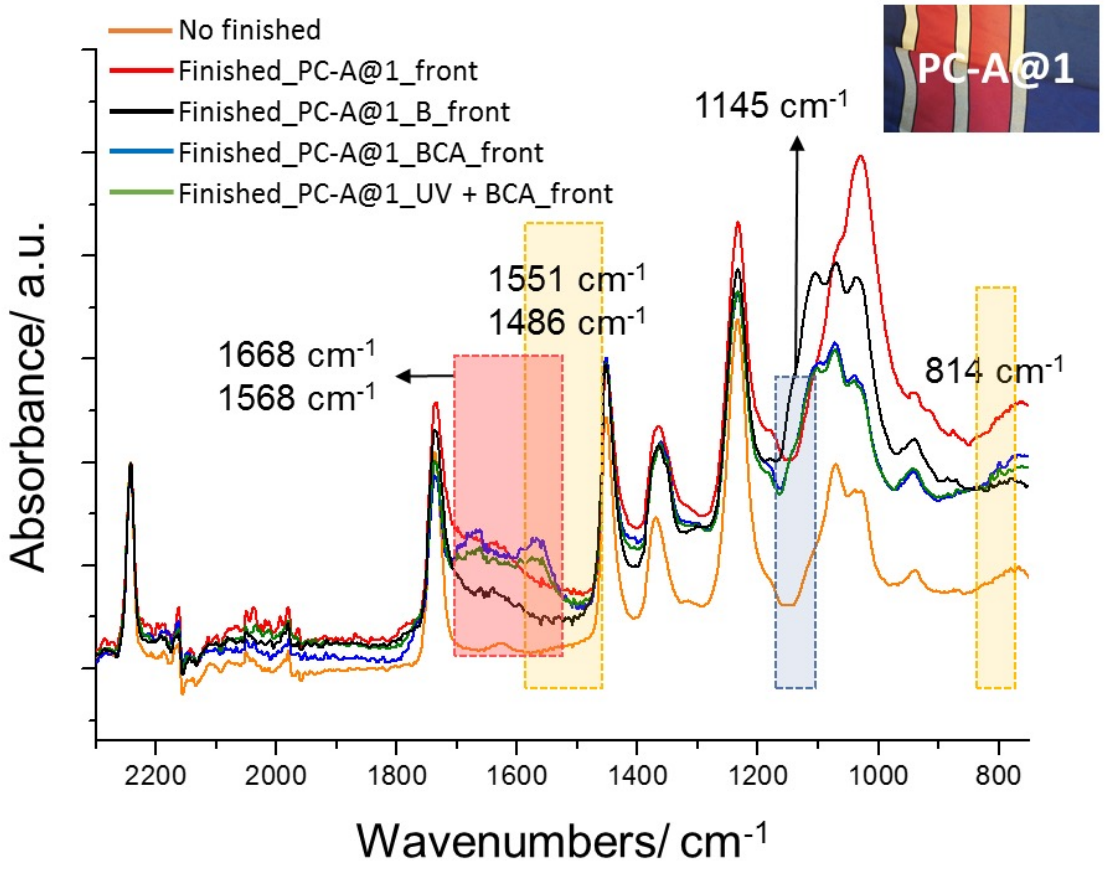
Finishing removal strategy on post-consumer fabrics “A” (PC-A@1): FTIR characterization of finished fabrics after removal strategies

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

As already demonstrated, the combination of treatments evidenced the **appearance of broad peaks** in the region 1560 and 1670 cm^{-1} assigned to the formation of:

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



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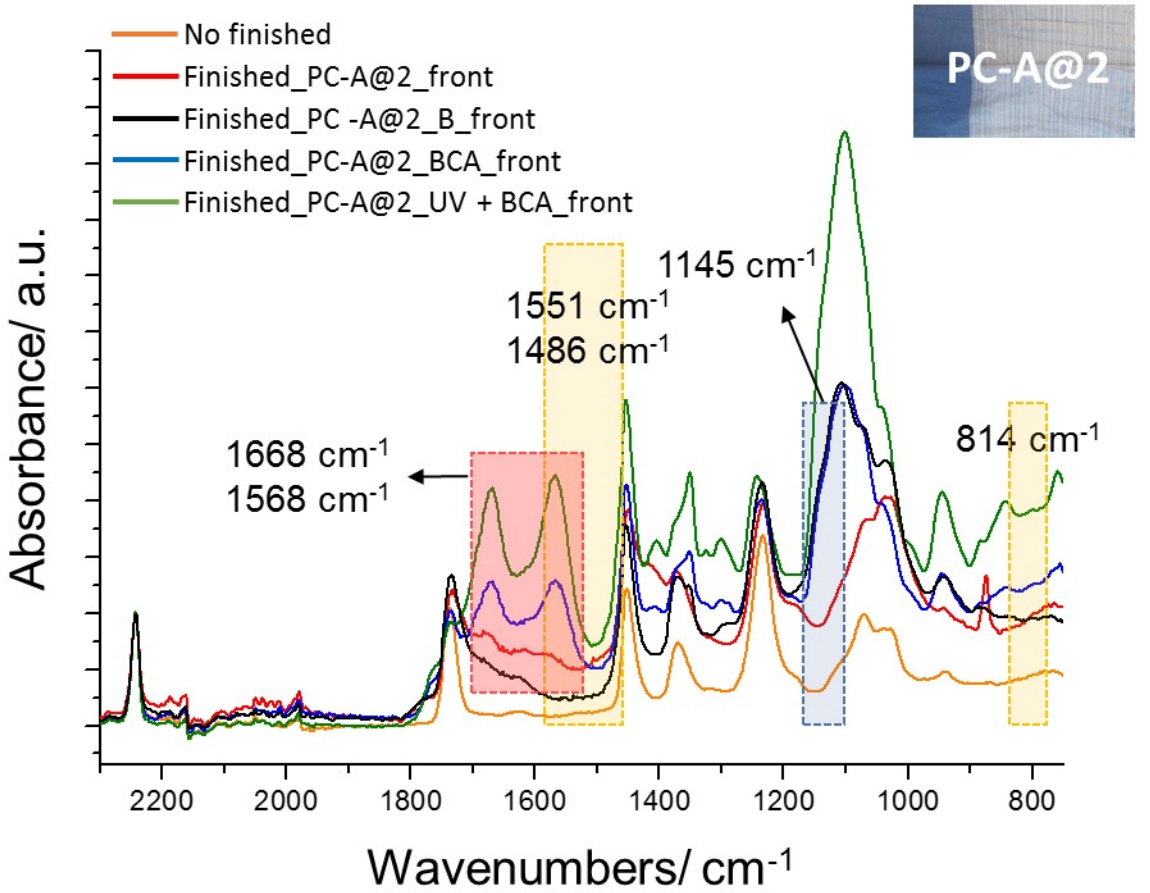
Finishing removal strategy on post-consumer fabrics "A" (PC-A@2): FTIR characterization of finished fabrics after removal strategies

They confirm **changes in the chemical structure of acrylic fibres** due to both the chemical treatments (in particular alkaline hydrolysis) and further textiles exposure to UV radiation.



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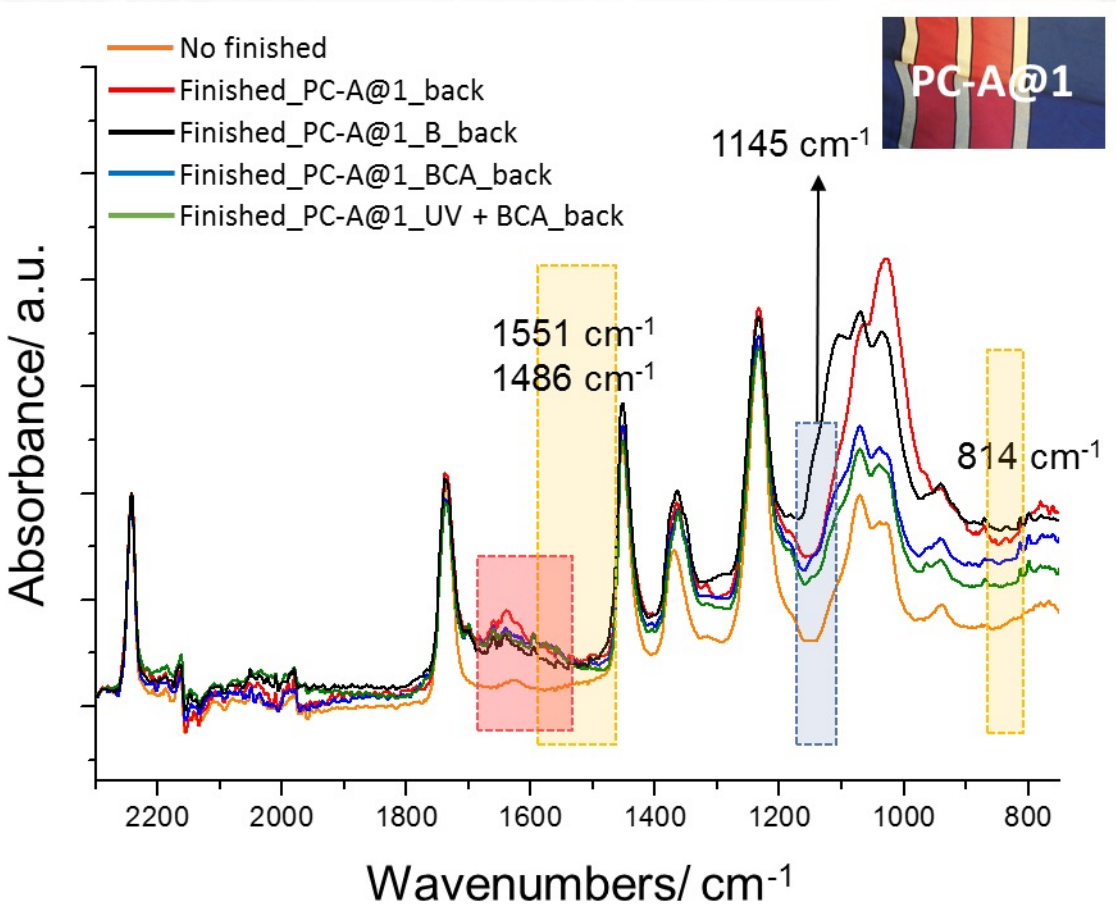
Contaminants removal from acrylic fabrics for outdoors applications: post-consumer fabrics "A" (PC-A@1)

FTIR characterization of treated fabrics

Conversely, IR spectra of the backside of fabrics did not reveal the presence of these peaks, thus confirming that the **long-lasting sunlight exposure of fabrics negatively influences the structure of the fibres** after the subsequent chemical removal treatments.

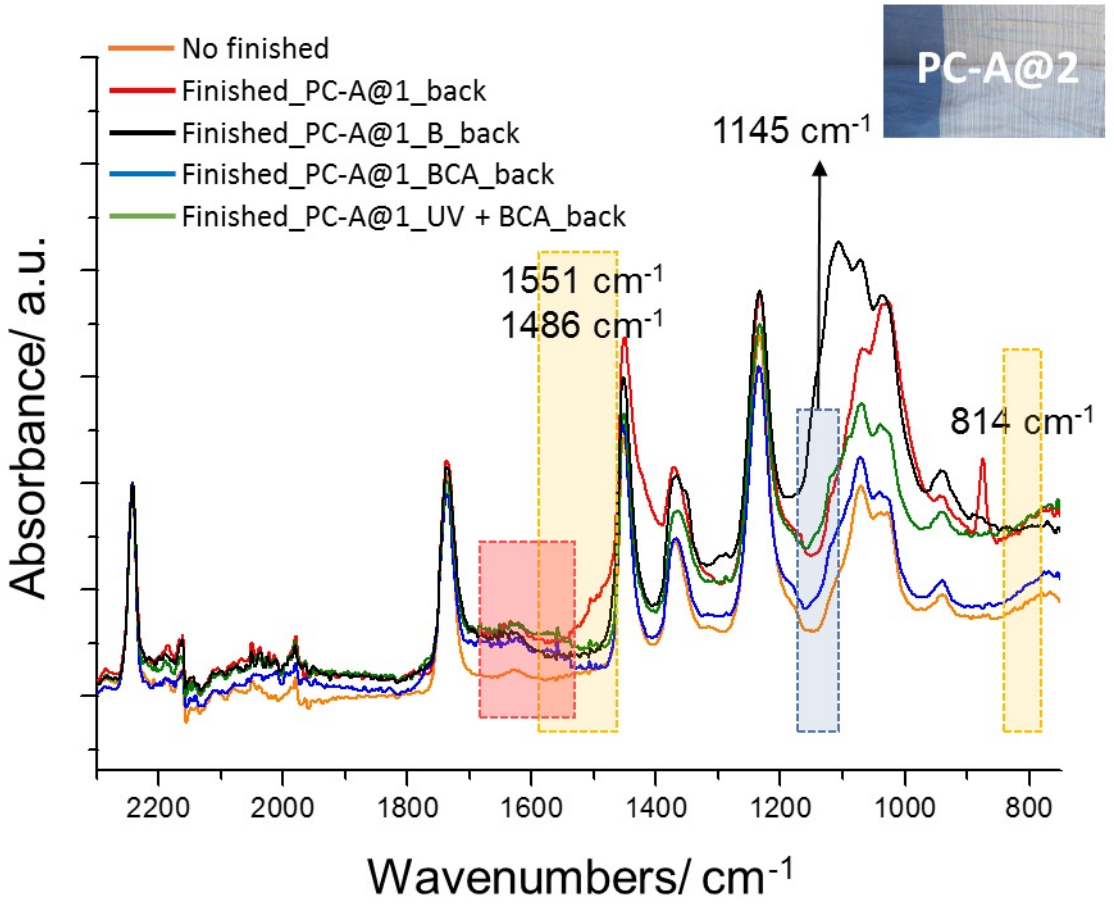


Removing chemicals from post-consumer outdoor textiles

Contaminants removal from acrylic fabrics for outdoors applications: post-consumer fabrics "A" (PC-A@2)

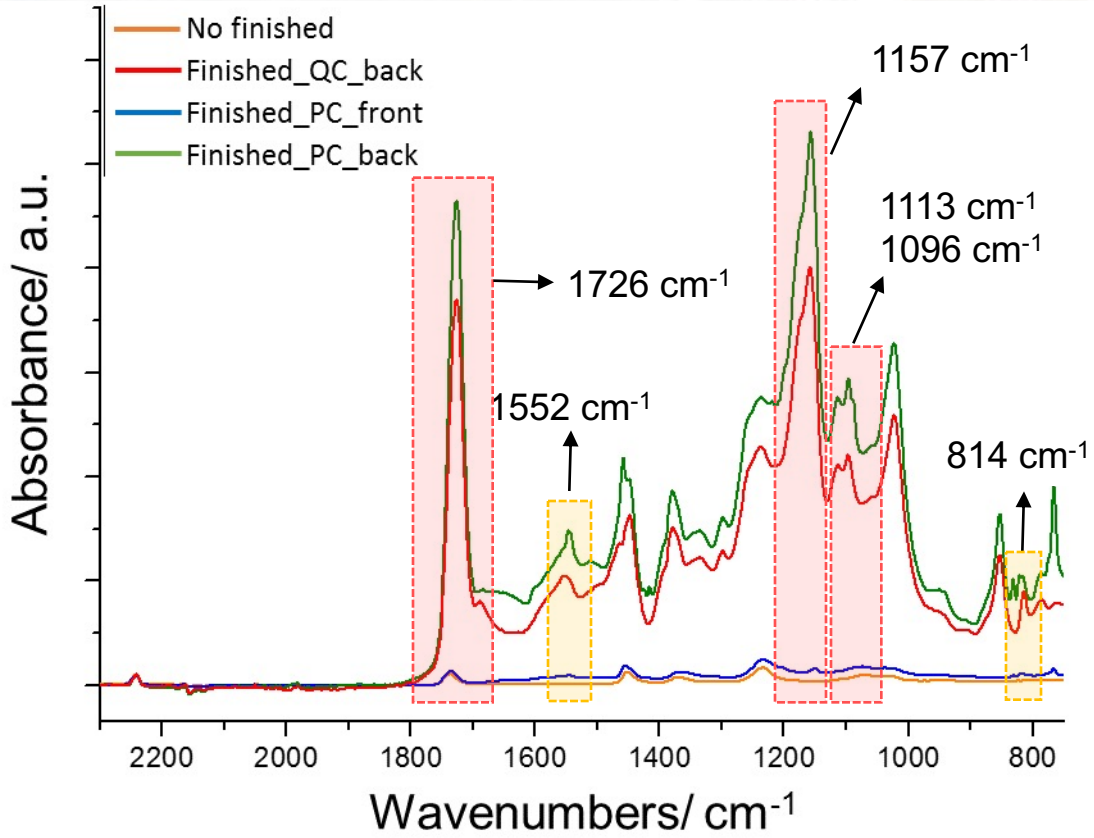
FTIR characterization of treated fabrics

Although the characteristic peaks of finishing are not clearly discernable, it could be concluded that the **performed strategies are efficient in the finishing removal.**



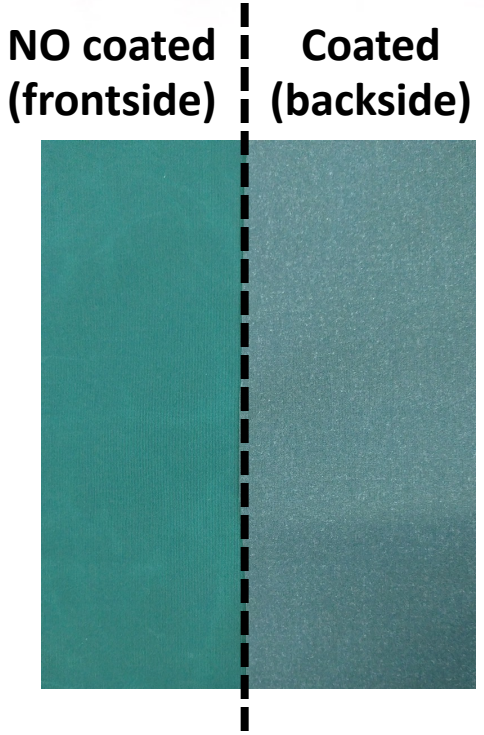
Removing chemicals from post-consumer outdoor textiles

Finishing removal strategy on post-consumer fabrics "B" (PC-B):
FTIR characterization of finished fabrics



Acrylic resin

Melamine resin



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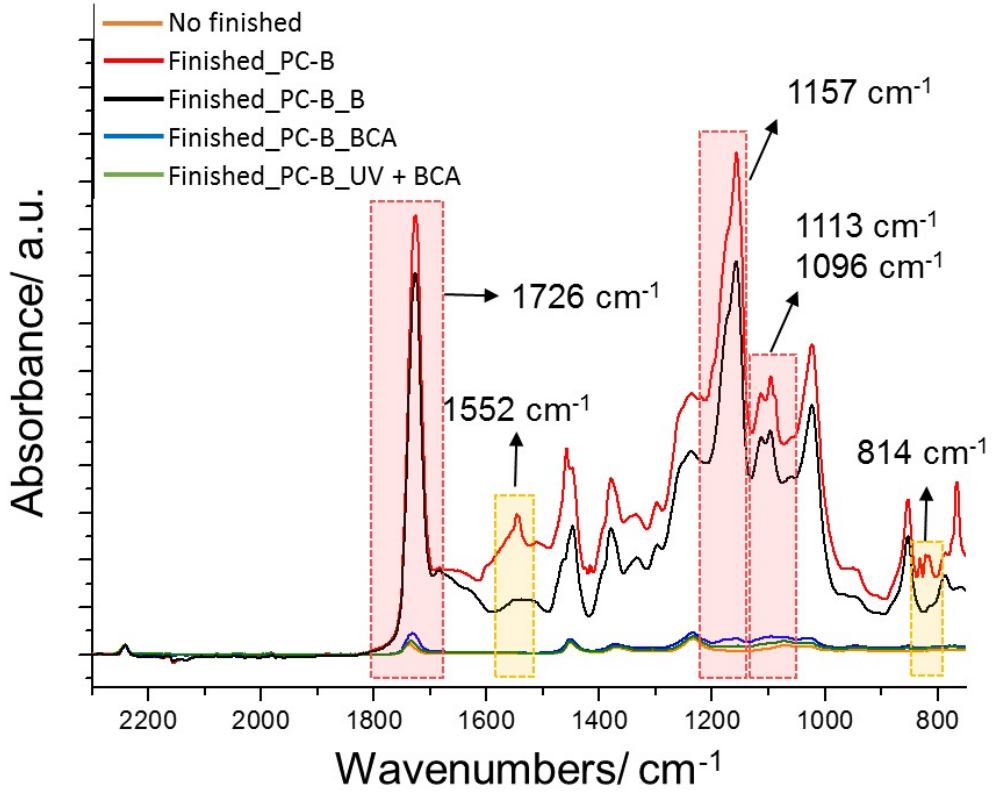
Finishing removal strategy on post-consumer fabrics “B” (PC-B):
FTIR characterization of finished fabrics after removal strategies



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.

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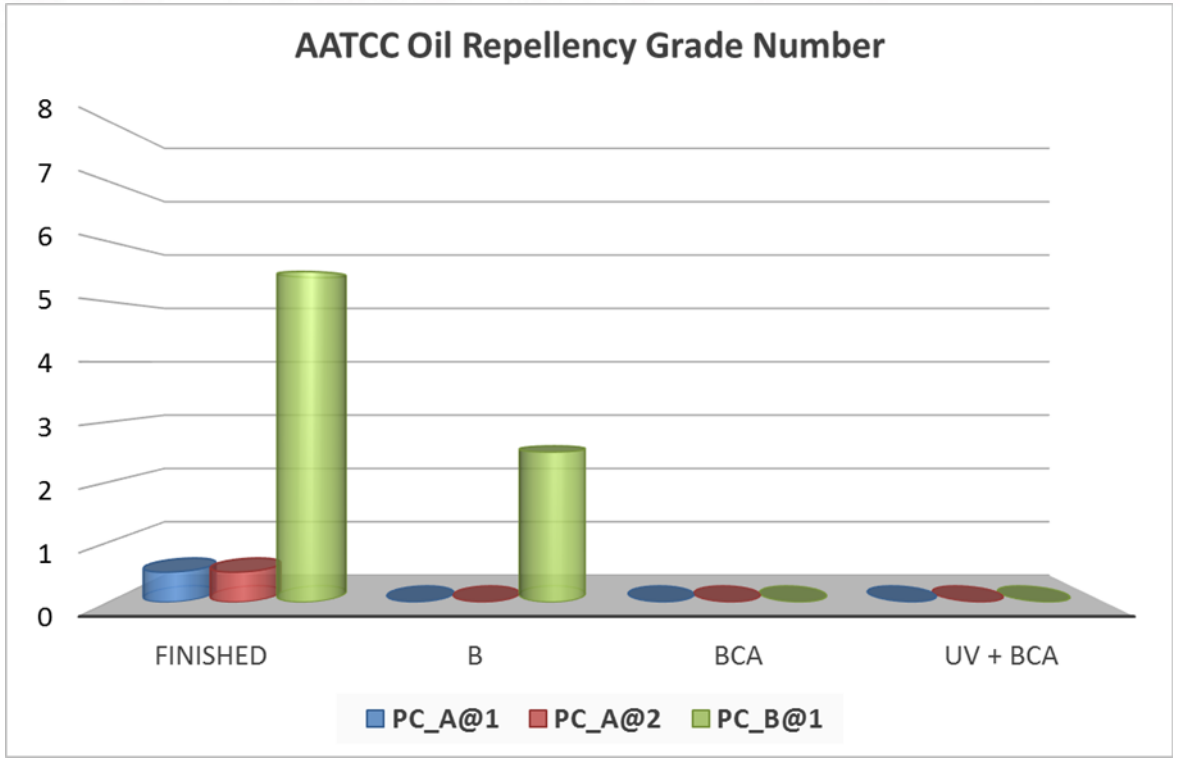
Finishing removal strategy on post-consumer fabrics “A”and “B” (PC-A@1, PC-A@2, PC-B): AATCC Test Method 118-2002: Oil Repellency

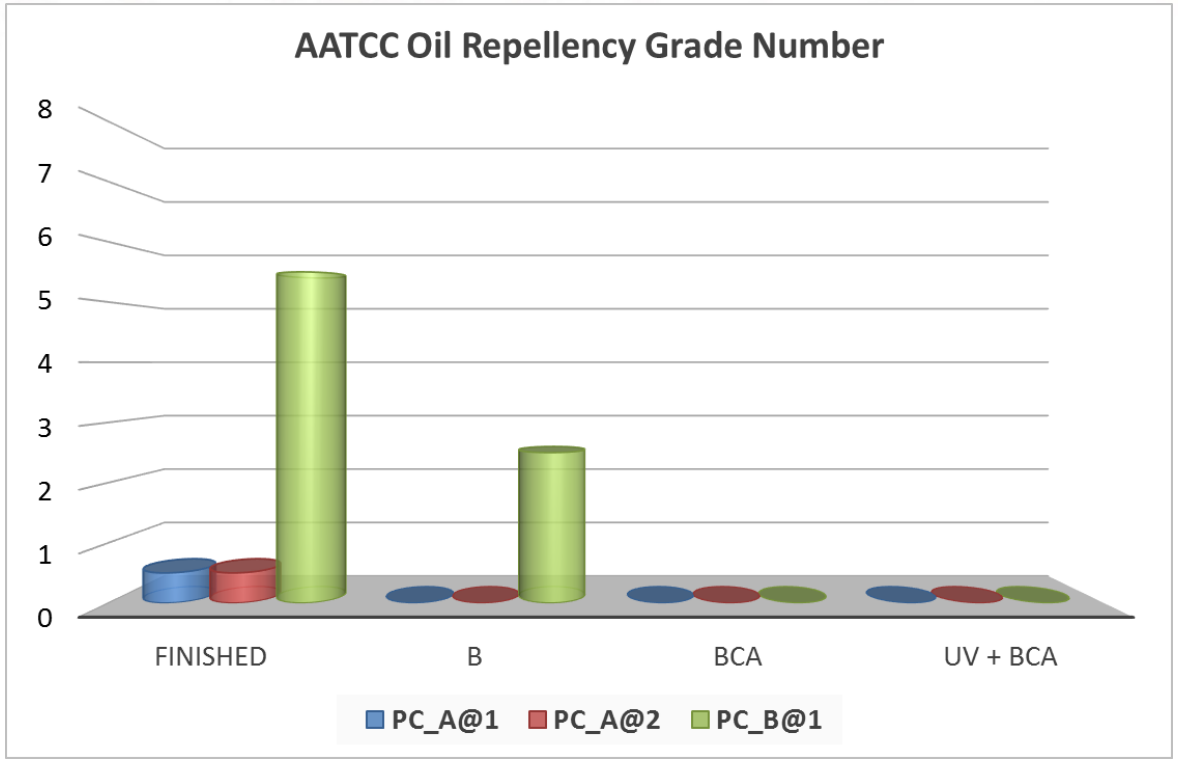
Since FTIR spectroscopy was not always explicative due to the detection limit of this technique, particularly for post-consumer "A" fabrics, the AATCC test method for oil repellency grade estimation was performed on both un-washed and washed fabrics.



Removing chemicals from post-consumer outdoor textiles

Finishing removal strategy on post-consumer fabrics “A”and “B” (PC-A@1, PC-A@2, PC-B): AATCC Test Method 118-2002: Oil Repellency

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



Removing chemicals from post-consumer outdoor textiles

Finishing removal strategy on post-consumer fabrics “A”and “B” (PC-A@1, PC-A@2, PC-B): Perfluorocarbon extraction (UNI CEN/TS 15968:2010)

B	PFOA	PFDA	PFDoA	PFTeA
PC_A-1	< LOD	< LOD	< LOD	< LOD
PC_A-2	0.03	0.02	0.03	0.04
PC_B	< LOD	< LOD	< LOD	< LOD

* Values reported in ppm

The singular acid hydrolysis removed residual fluorocarbon resin from fabric "A” and “B”, thus leading to not detectable PFCs values or lower than 1 ppm.

Removing chemicals from post-consumer outdoor textiles

Finishing removal strategy on post-consumer fabrics “A”and “B” (PC-A@1, PC-A@2, PC-B): Perfluorocarbon extraction (UNI CEN/TS 15968:2010)

BCA	PFOA	PFDA	PFDoA	PFTeA
PC_A-1	< LOD	< LOD	< LOD	< LOD
PC_A-2	< LOD	< LOD	< LOD	< LOD
PC_B	< LOD	< LOD	< LOD	< LOD
UV + BCA	**PFOA**	**PFDA**	**PFDoA**	**PFTeA**
PC_A-1	< LOD	< LOD	< LOD	< LOD
PC_A-2	< LOD	< LOD	< LOD	< LOD
PC_B	< LOD	< LOD	< LOD	< LOD

* Values reported in ppm

PFCs extraction of washed samples with the combined chemical treatments and dry conditions confirmed the efficacy of the removal processes that led to **"cleaned" acrylic fabrics** for a "second life".

Removing chemicals from post-consumer outdoor textiles

Conclusions

- The long-lasting sunlight exposure of acrylic fabrics led to **partial removal of the applied finishing** due to photodegradation processes;
- The finishing removed from fabrics during their life represents a **serious environmental issue** to be overcome with the use of the most recent environmentally friendly finishing, formaldehyde- and PFC- free;
- The combination of both chemical treatments and photodegradation process of post-consumer fabrics reveals the **total removal of both finishing**, although changes in the **chemical structure of acrylic fibres** was observed due to the long-lasting exposure to sunlight;
- The combined treatments allow obtaining **cleaned fabrics** for a "second life" to be used with environmentally friendly finishing.

Removing chemicals from post-consumer outdoor textiles

Future goals

- Further investigation will be performed to **optimize the removal process** reducing the changes in chemical structure of the post-consumer acrylic fibres thus assesing and **preserving the mechanical properties**;

- The process will be implemented by reusing the obtained "cleaned acrylic fabrics" using **environmentally-friendly finishing**.

THANKS FOR YOUR ATTENTION

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