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LEARNING GUIDE

NIR & SWIR HYPERSPECTRAL LINE SCAN IMAGER FOR AUTOMATIC TEXTILE SORTING

cea

Boer Group

HORIBA

Aalto University

MISTERY PROJECT

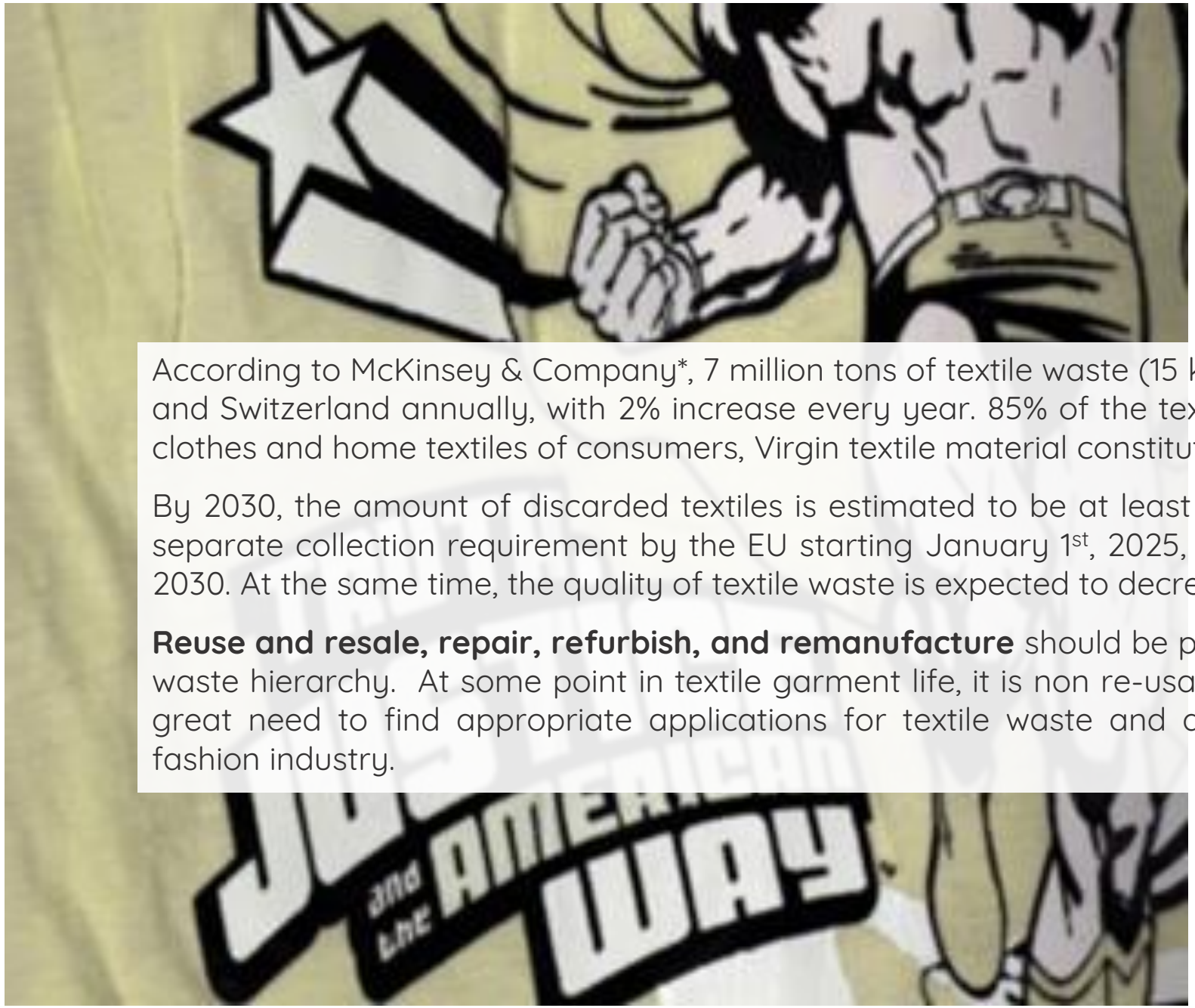
co-financed by

Re_fashion

For a 100% circular textile industry

Photo credit : GEBETEX

Context and Objectives



Context

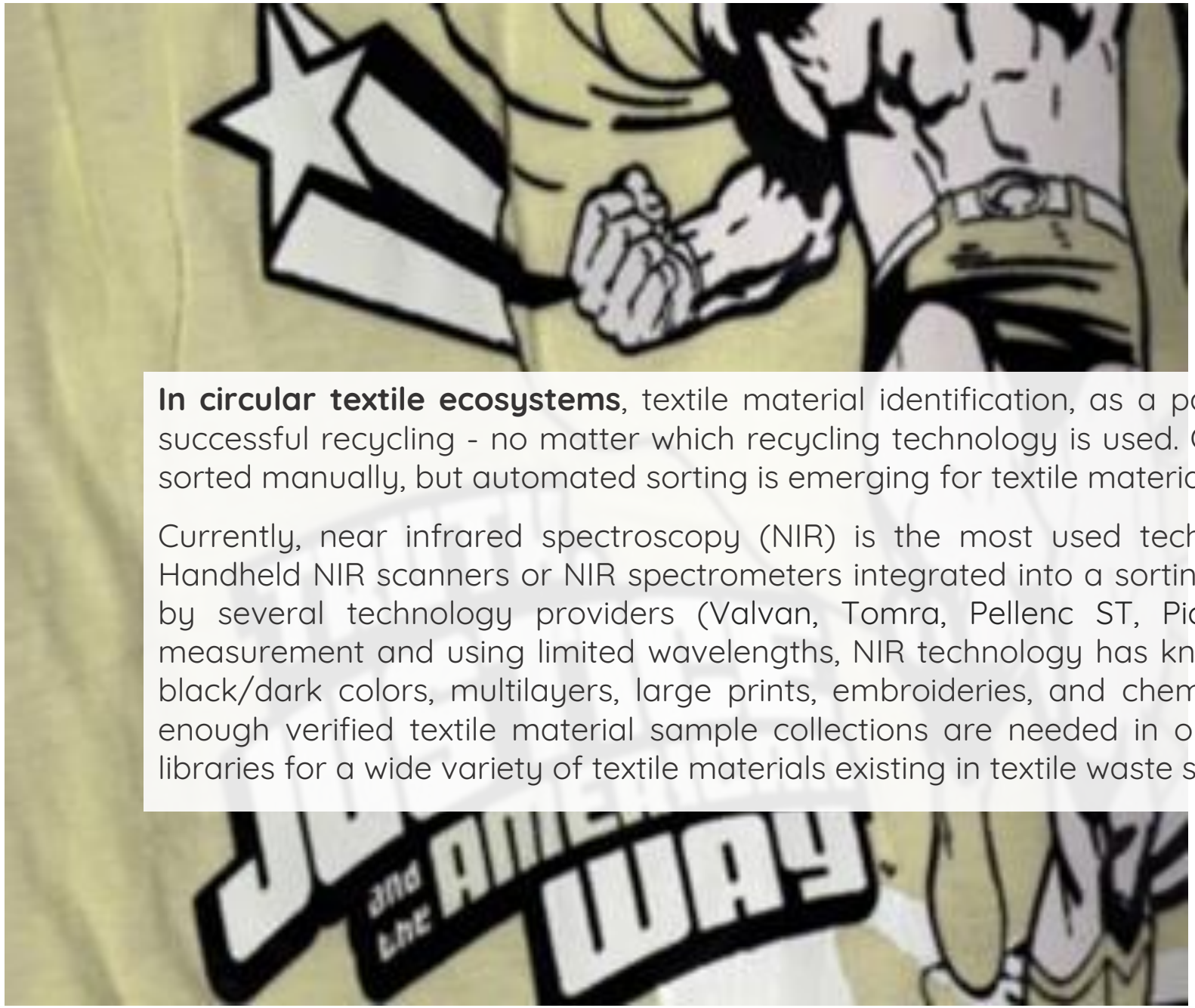
According to McKinsey & Company*, 7 million tons of textile waste (15 kg per person) is generated in the EU and Switzerland annually, with 2% increase every year. 85% of the textile waste originates from discarded clothes and home textiles of consumers, Virgin textile material constitutes 99% of textile waste.

By 2030, the amount of discarded textiles is estimated to be at least 8.5 million tons, with the mandatory separate collection requirement by the EU starting January 1st, 2025, it could increase by another 50% by 2030. At the same time, the quality of textile waste is expected to decrease.

Reuse and resale, repair, refurbish, and remanufacture should be prioritized over recycling according to waste hierarchy. At some point in textile garment life, it is non re-usable, and will be discarded. There is a great need to find appropriate applications for textile waste and advance of circularity of textile and fashion industry.

** Ref : "Scaling textile recycling in Europe – Turning waste into value" by McKinsey & Company, 2022*

Photo credit : Ihab MAKKI



Context

In circular textile ecosystems, textile material identification, as a part of the sorting process, is key for successful recycling - no matter which recycling technology is used. Currently, most of the textile waste is sorted manually, but automated sorting is emerging for textile material identification for recycling.

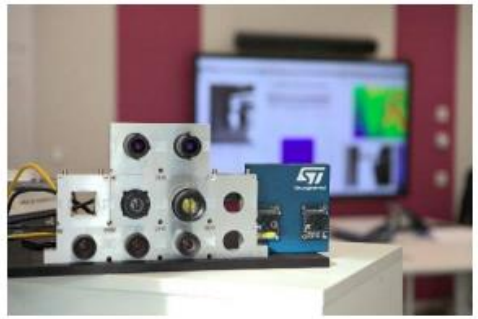
Currently, near infrared spectroscopy (NIR) is the most used technology to identify textile materials. Handheld NIR scanners or NIR spectrometers integrated into a sorting line are being used and developed by several technology providers (Valvan, Tomra, Pellenc ST, Picvisa)*. Being a point and surface measurement and using limited wavelengths, NIR technology has known challenges in identifying blends, black/dark colors, multilayers, large prints, embroideries, and chemicals. In addition, reliable and large enough verified textile material sample collections are needed in order to build representative spectral libraries for a wide variety of textile materials existing in textile waste streams.

* Ref : “Textile sorting, recognition and disassembly technologies, Refashion, April 23

Photo credit : Ihab MAKKI

Objectives

MISTERY



The MISTERY (**M**ultispectral Optical **S**ensors for **TE**xtiles Rec**Y**cling), collaborative project, undertaken by the CEA YSPOT as part of the IRT Nanoelec, aims at prototyping the use of multispectral optical sensors in characterising used household textiles. The tests will be carried out under industrial conditions with support provided by Boer Group Recycling Solutions at the Gebetex sorting centre. The two other project partners are Aalto University, expert in the use of optical sensors for textile sorting, and Horiba Scientific, specialist in the production of analytical and measuring technologies.

Source : « Communiqué de presse Innovative Challenge 2021 - EN.pdf » - https://refashion.fr/

The objective of the MISTERY project was to find out if hyperspectral imaging as a line scanner mode can be used to improve textile material identification. The following three use cases were selected for the focus of the project:

1. Identification of small amounts of **elastane** (EA) in cotton (CO): target 2% elastane
2. Identification of **polyamide** (PA); especially polyamide 6 (PA6) and polyamide 6,6 (PA6,6)
3. Identification of cotton vs. **cellulosics**; especially cotton vs. **viscose**
4. Identification of composition of **Polycotton**
5. Identification of material of **black or dark** garment

Photo credit : Refashion textiles library

Major challenges

Summary of the non-identifiable or problematic materials and contaminants in textile materials identification

BLENDS

Major challenges

Issue

- NIR spectra of different textile materials overlap, typically at about 1500 nm
  Challenging to separate and identify per material, at least not quantitatively

- Blends can appear in many forms, such as:
  - A yarn is made of two or more textile materials
  - A core of the yarn is a different material to the surface of the yarn (for example elastane is spun inside cotton)
  - Weave and weft are made out of different textile material
  - Multilayer textile products having layers made out of different materials could also be classified as blends

Photo credit : Refashion textiles library

Major challenges

MULTILAYERS

Issue

- NIR optics does not penetrate and therefore not reach inner layers of a garment

  Skiing jackets having an outside layer from cotton and lining made from polyester as an example

Photo credit : GEBETEX

Major challenges

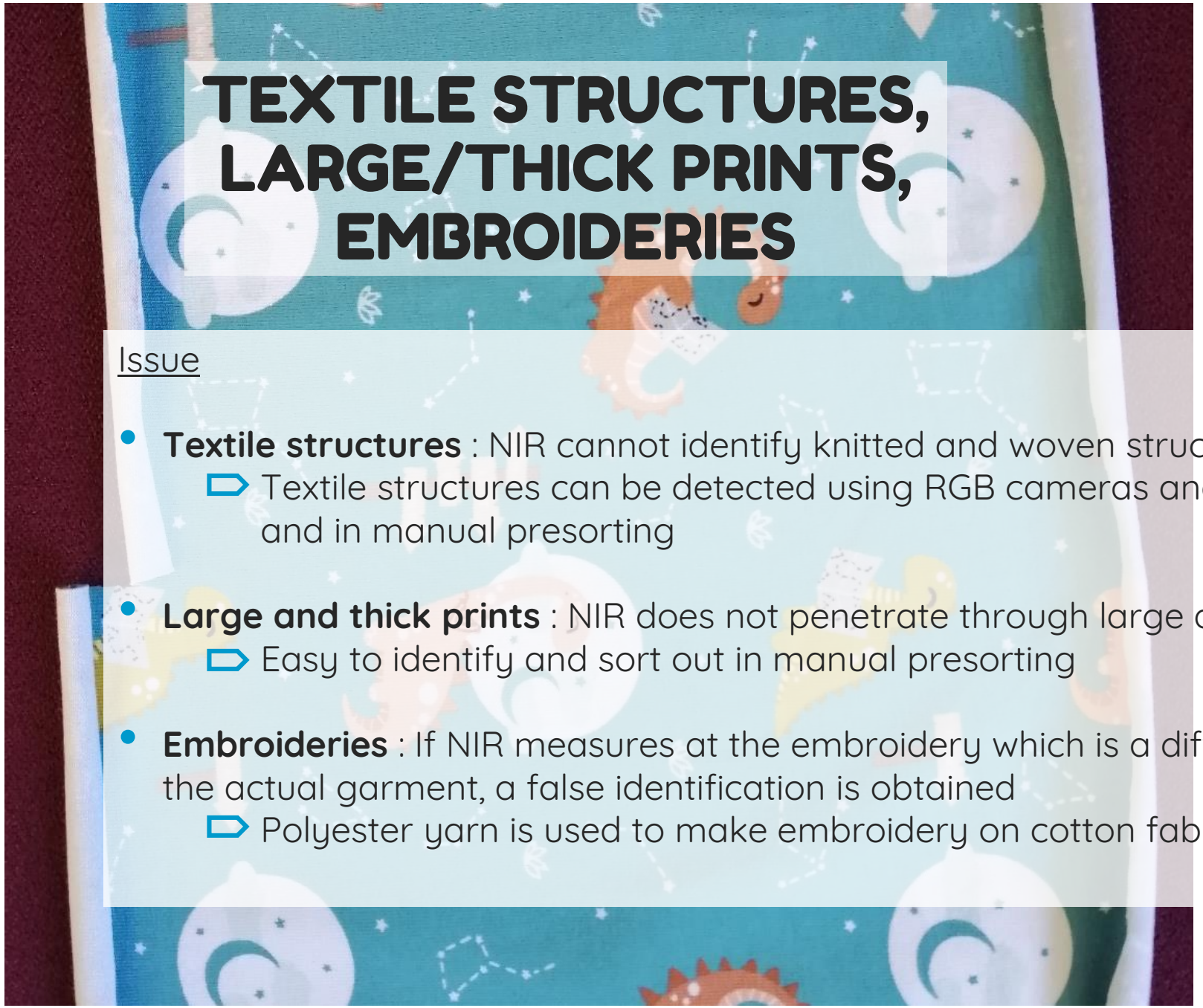
BLACK/DARK COLOURS

Issue

- Black and dark colors interfere with NIR optics *
  - Typical challenging wavelength area at 1100-1150 nm
  - Polyester, polyamide and wool have the most issues
  - Some pigments cause high absorption of light and therefore no light is reflected back to the analyzer and identification cannot be performed
  - Carbon black used in dyeing synthetics is a typical example

Photo credit : Refashion textiles library

** From BSc thesis by Niko Rintala - NIRS identification of black textiles : Improvements for waste textiles sorting https://www.theseus.fi/handle/10024/226829*



TEXTILE STRUCTURES, LARGE/THICK PRINTS, EMBROIDERIES

Major challenges

Issue

- **Textile structures** : NIR cannot identify knitted and woven structures
  - ⇨ Textile structures can be detected using RGB cameras and machine vision, and in manual presorting
- **Large and thick prints** : NIR does not penetrate through large and thick prints
  - ⇨ Easy to identify and sort out in manual presorting
- **Embroideries** : If NIR measures at the embroidery which is a different material than the actual garment, a false identification is obtained
  - ⇨ Polyester yarn is used to make embroidery on cotton fabric as an example

Photo credit : Refashion textiles library

CONTAMINANTS HARMFUL CHEMICALS

Major challenges

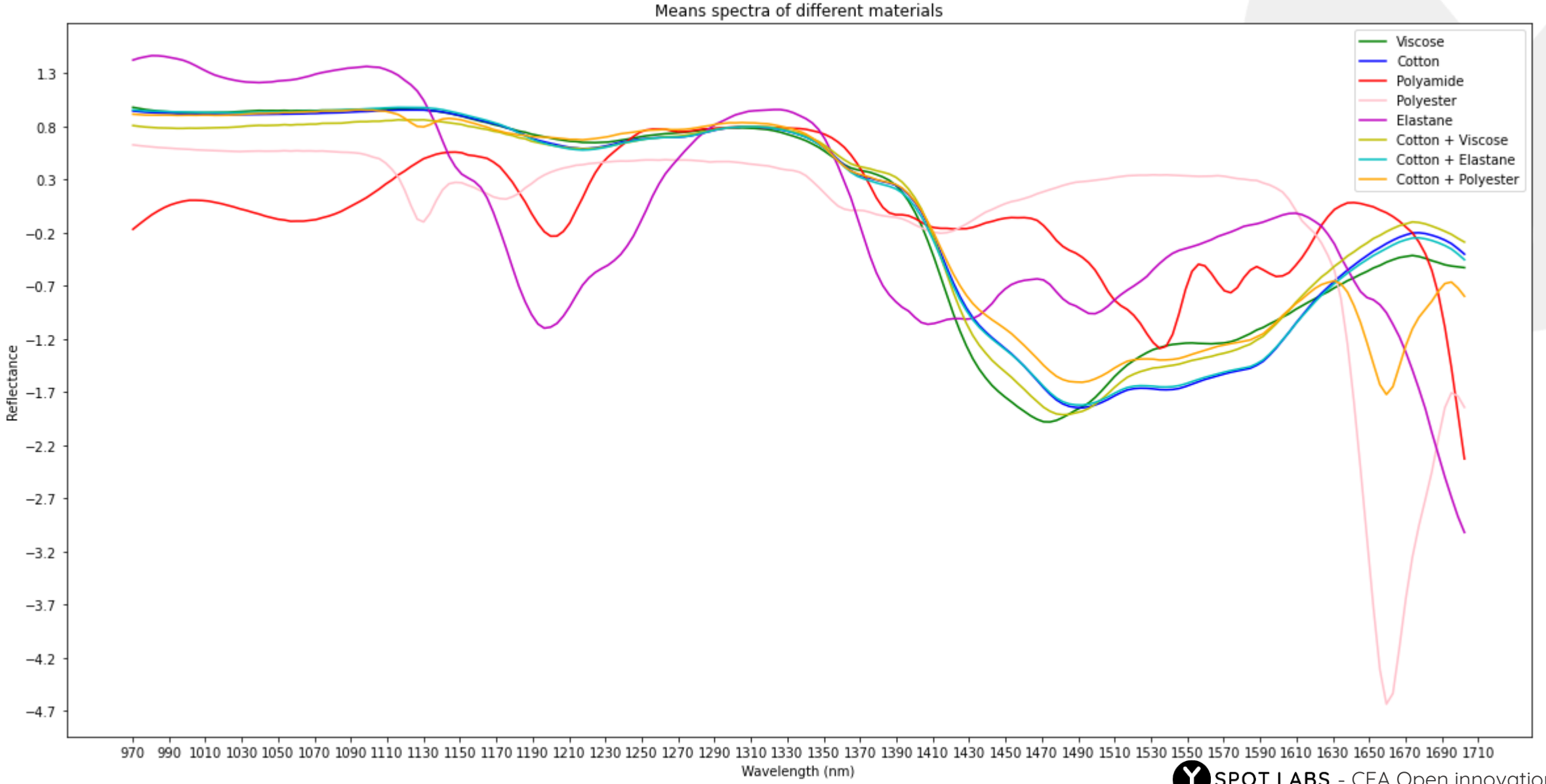
Issue

- There are thousands of chemicals used in textile industry, some of them in small quantities
- Some chemical are harmful and non-compliant according to legislation
- NIR can detect organic compounds only
- It is not realistic to have spectral libraries for all the chemicals used in textile manufacturing

Photo credit : Refashion textiles library

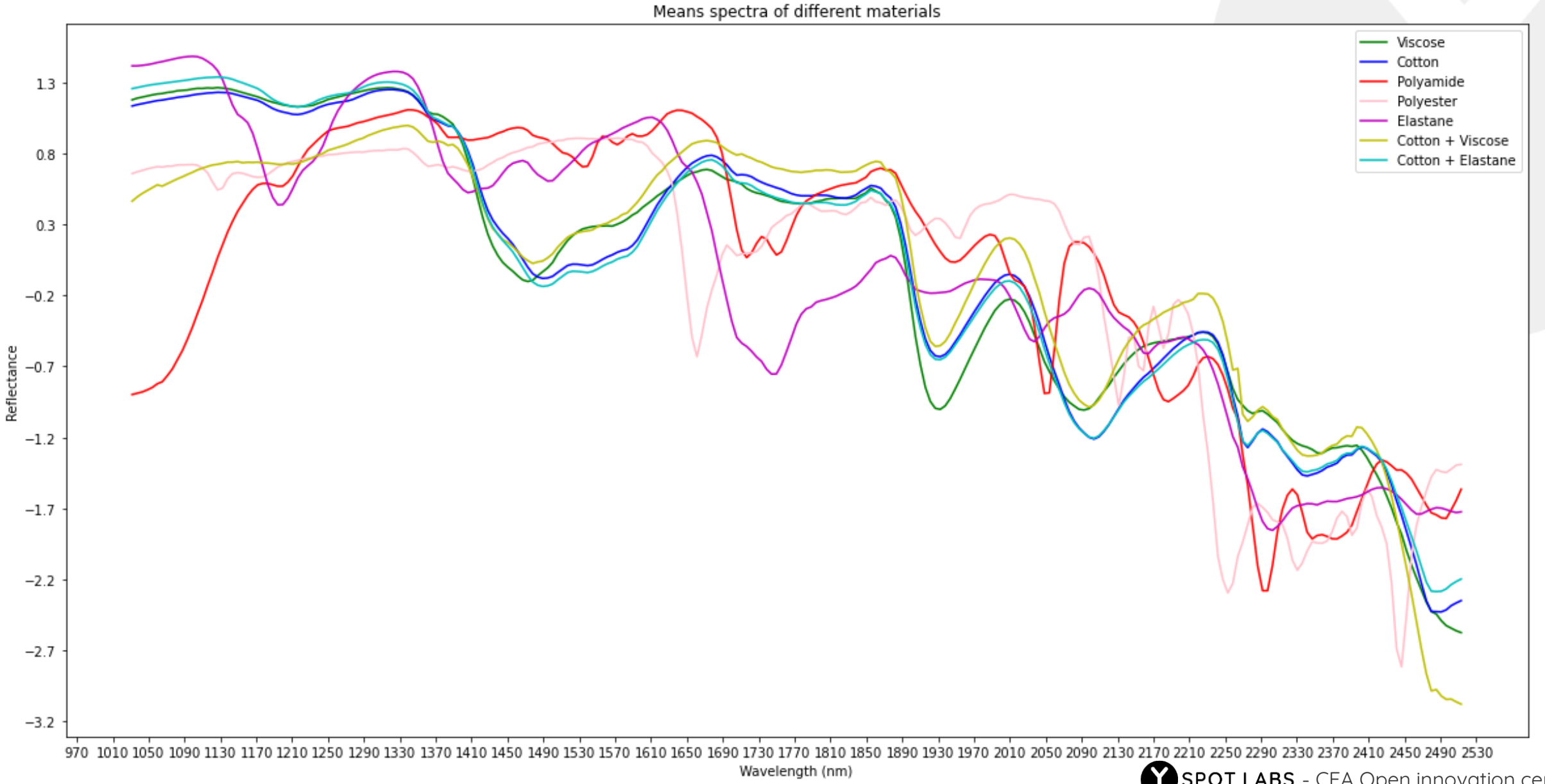
Experimentation Results

RESULTS OF SPECTRAL ACQUISITION IN VNIR (900-1700nm)



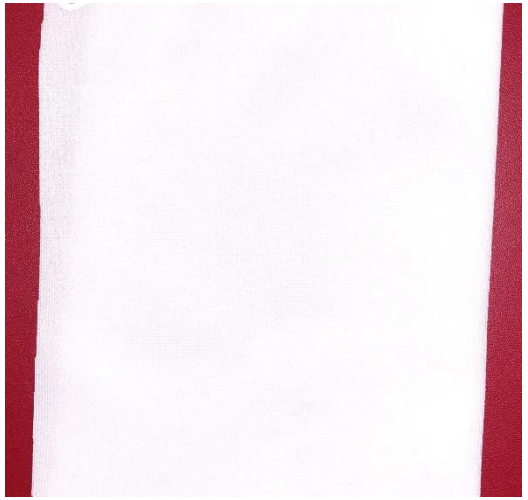
Graph credit : CEA PIMS Bordeaux

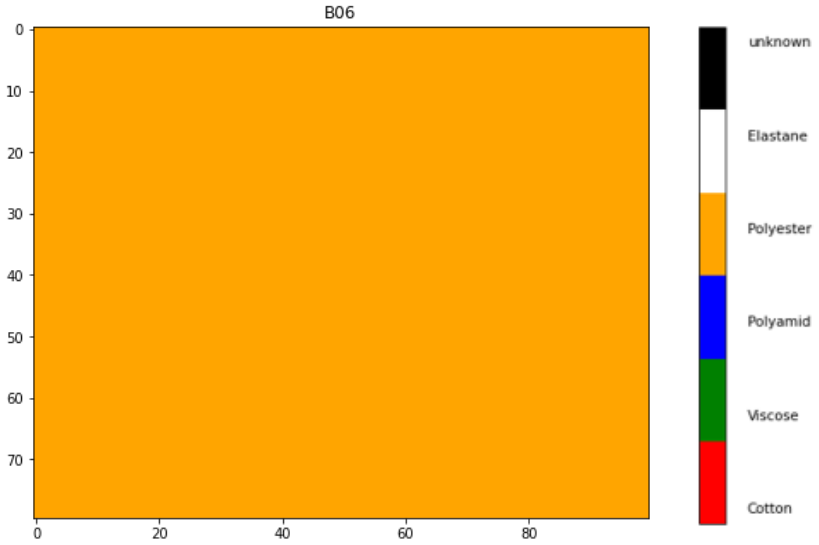
RESULTS OF SPECTRAL ACQUISITION IN SWIR (1000-2500nm)



Graph credit : CEA PIMS Bordeaux

POLYESTER RESULTS



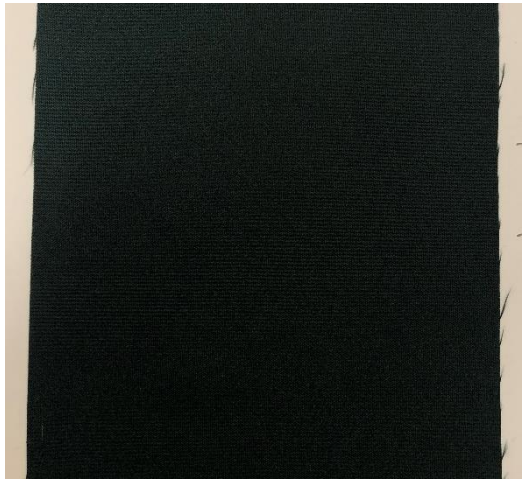


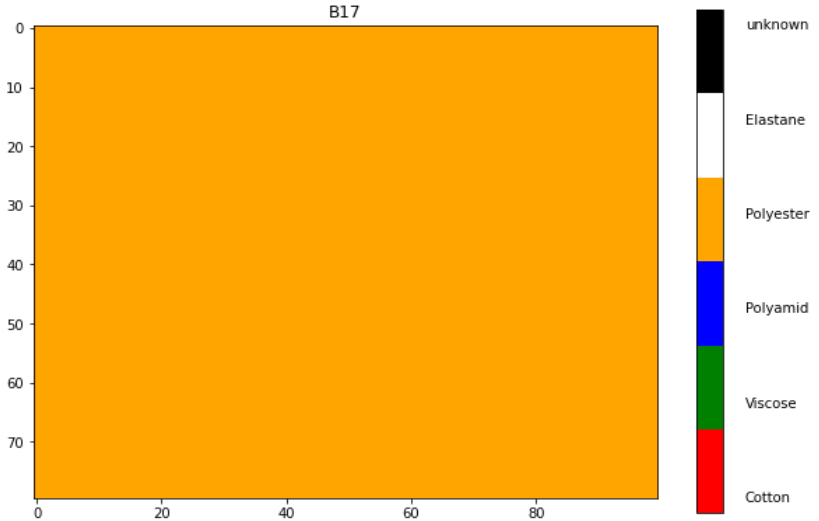
Polyester 100

Polyester 100

NIR LINEAR

Polyester 100





Polyester 100

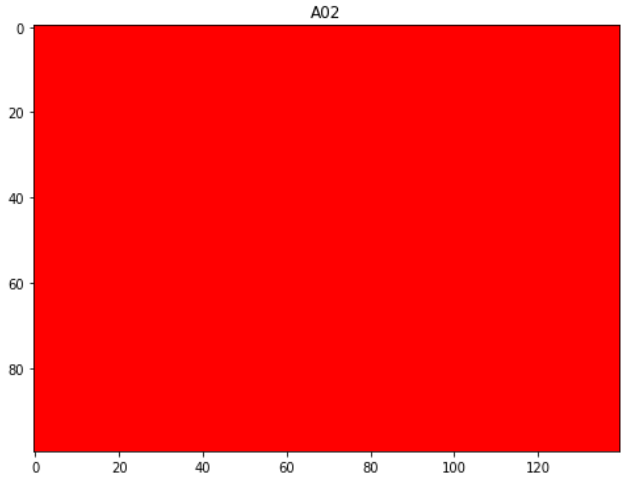
Polyester 100

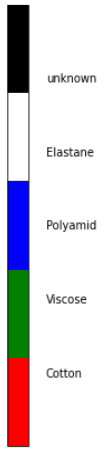
NIR LINEAR

Polyester 100

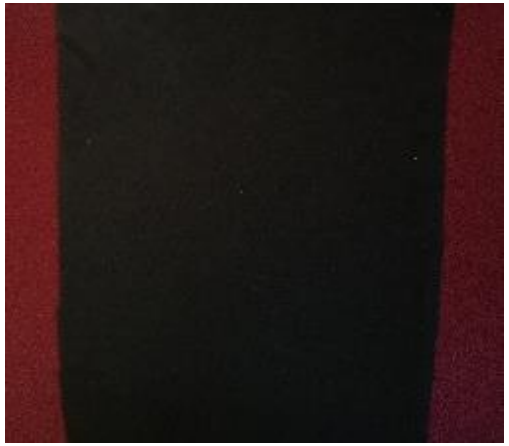
Photo credit : Refashion textiles library

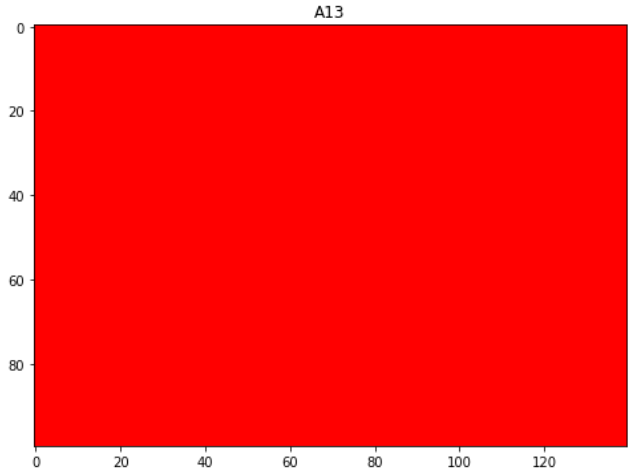
COTTON RESULTS

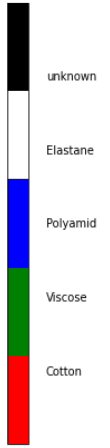




	Cotton	100
	Cotton	100
NIR LINEAR	Cotton	100



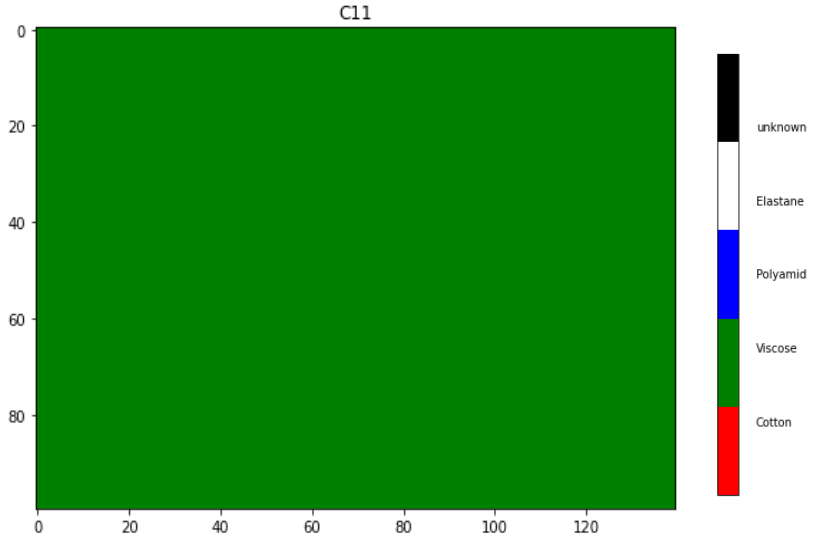




	Cotton	100
	Cotton	100
NIR LINEAR	Cotton	100

Photo credit : Refashion textiles library

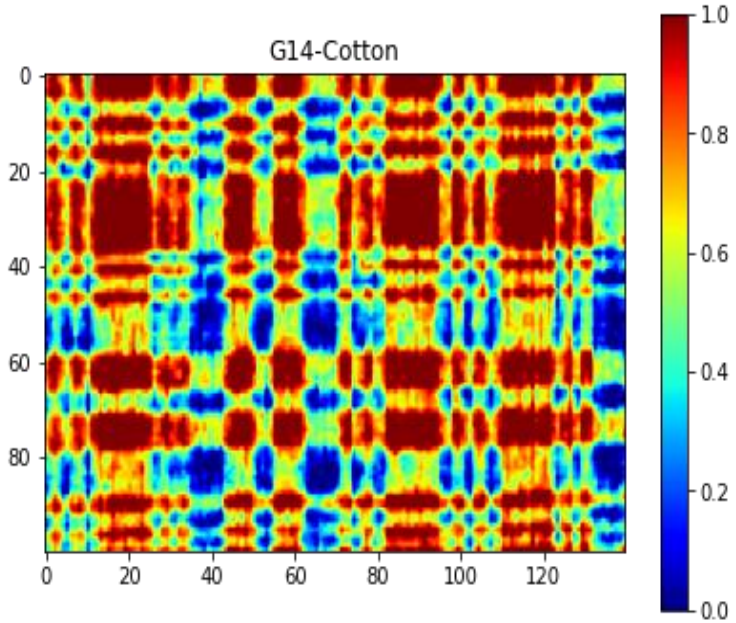
VISCOSE AND BLEND VISCOSE/COTTON RESULTS



Viscose 100

Viscose 100

NIR LINEAR Viscose 100



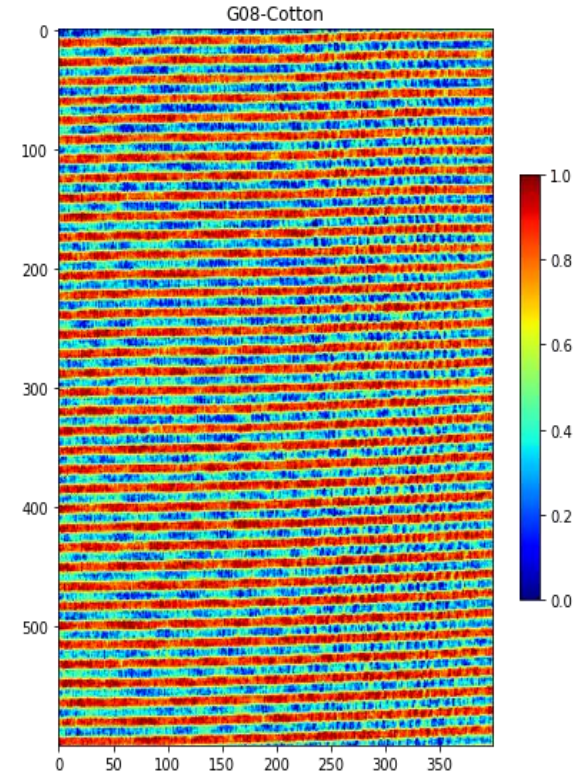
Cotton 65
Viscose 35

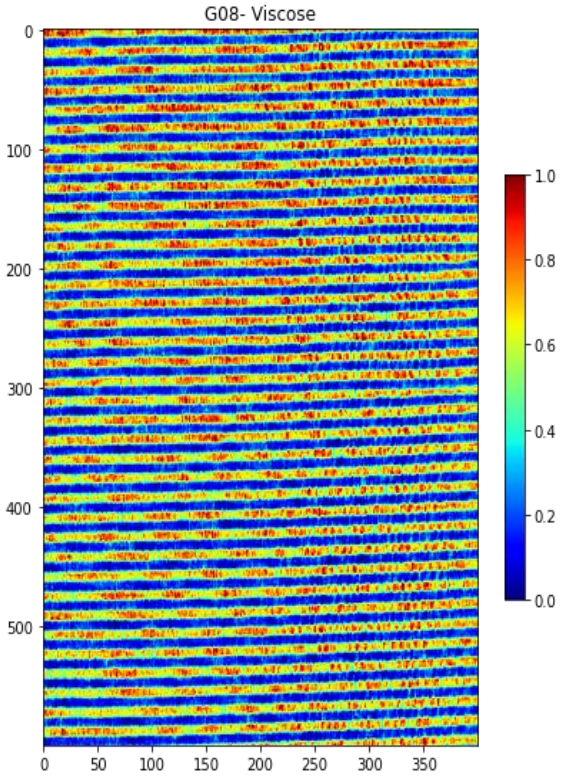
Cotton 58
Viscose 42

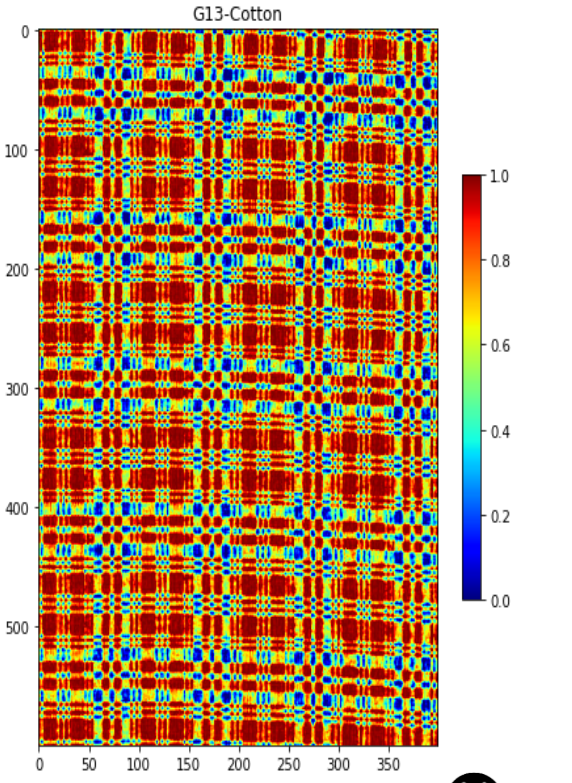
NIR LINEAR Cotton 65
Viscose 35

Photo credit : Refashion textiles library

LARGE VISION OF BLEND VISCOSE/COTTON







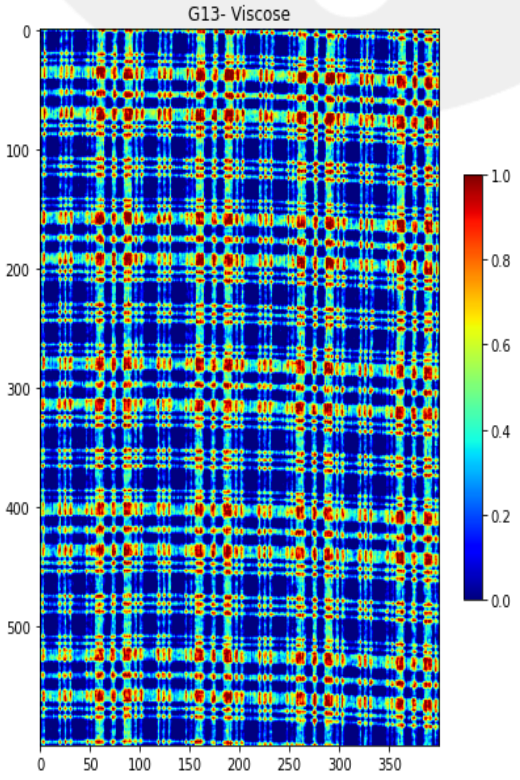
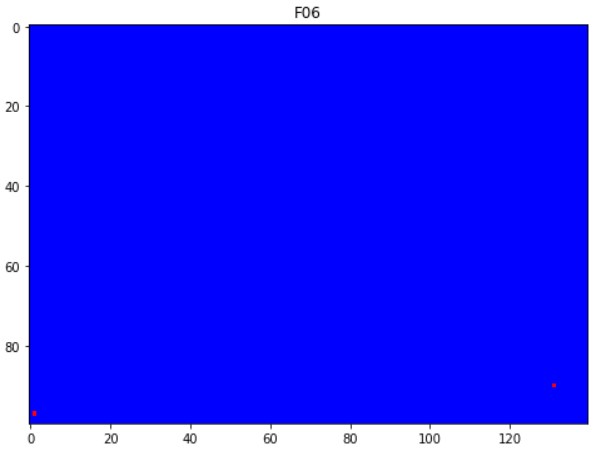
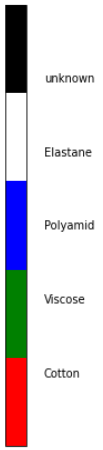


Photo credit : Refashion textiles library

POLYAMIDE RESULTS

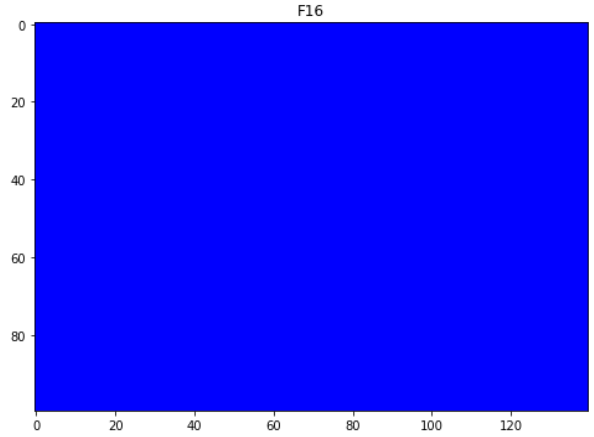


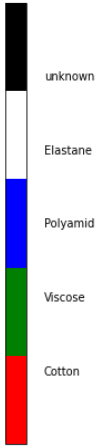


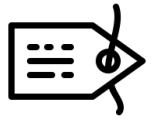
Polyamide 100

Polyamide 100
PA 6

Polyamide 100







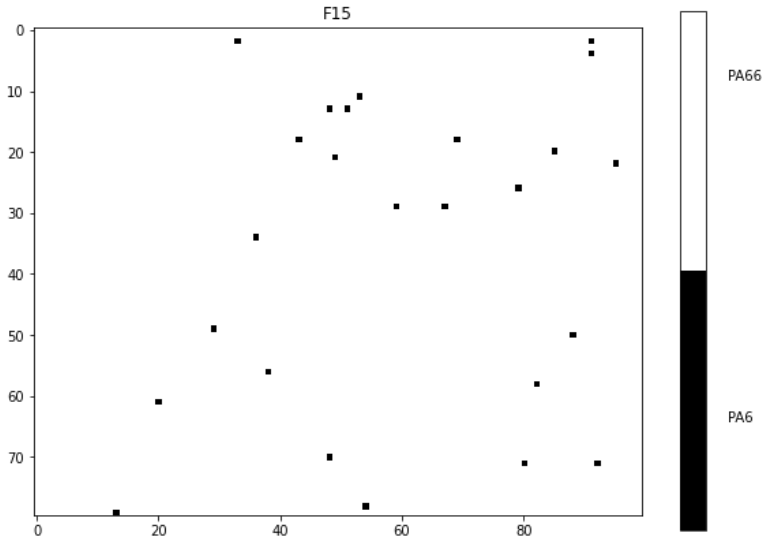
Polyamide 100

Polyamide 100
PA 6.6

Polyamide 100

Photo credit : Refashion textiles library

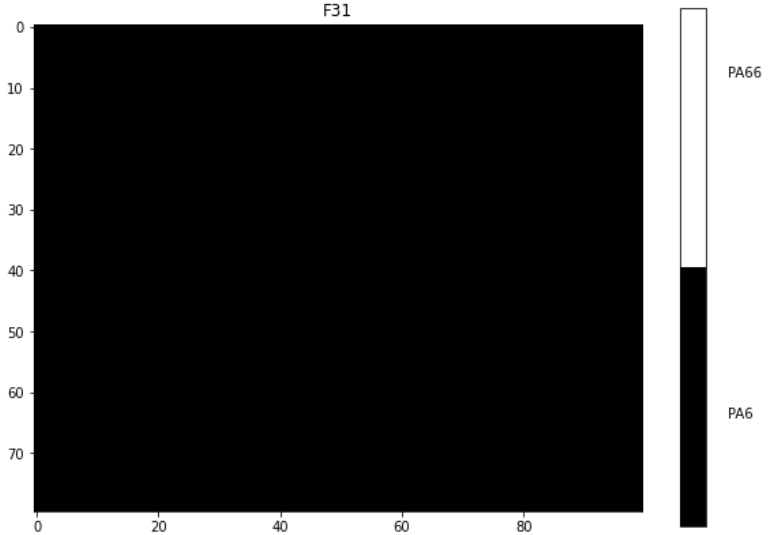
POLYAMIDE RESULTS : PA6 or PA6.6



Polyamide 100

Polyamide 100
PA 6.6

Polyamide 100
PA 6.6



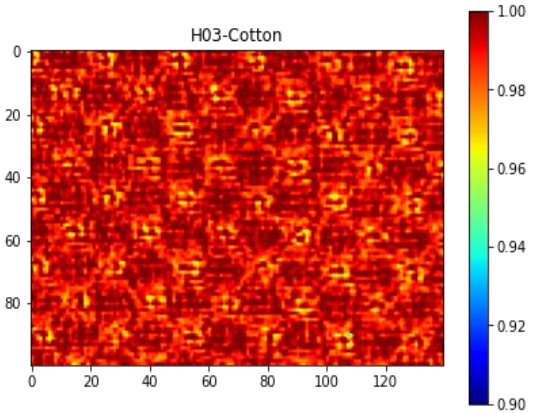
Polyamide 100

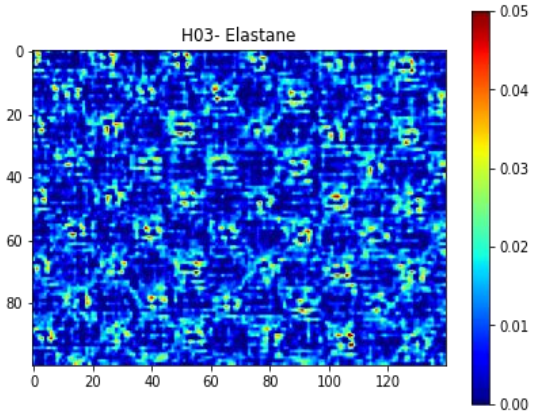
Polyamide 100
PA 6

Polyamide 100
PA 6

Photo credit : Refashion textiles library

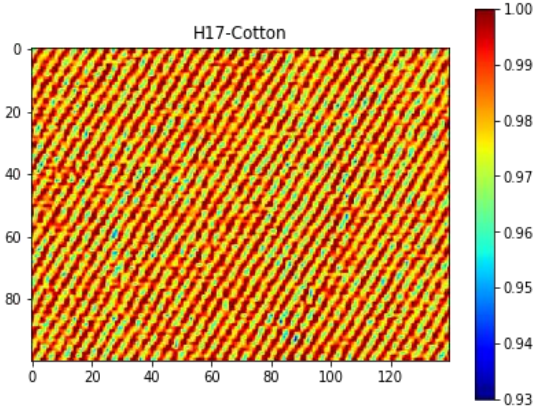
BLEND ELASTANE/COTTON RESULTS

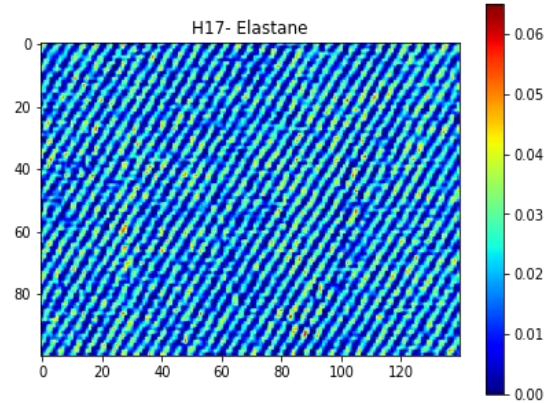




	Cotton	96
	Elastane	4
	Cotton	96
	Elastane	4
NIR LINEAR	Cotton	99
	Elastane	1

H17

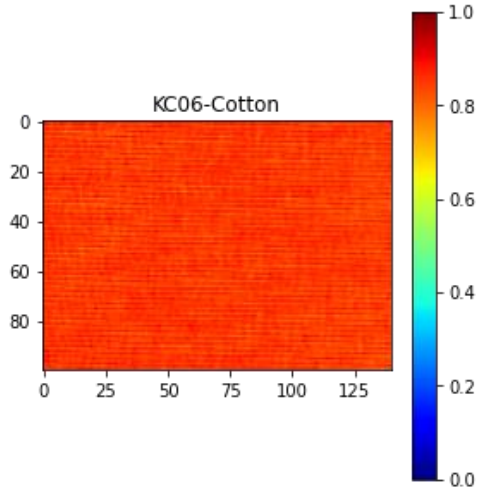


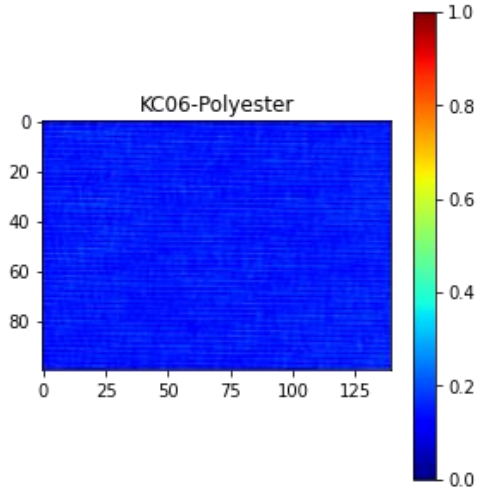


	Cotton	99
	Elastane	1
	Cotton	97
	Elastane	3
NIR LINEAR	Cotton	98
	Elastane	2

Photo credit : Refashion textiles library

BLEND POLYESTER/COTTON RESULTS



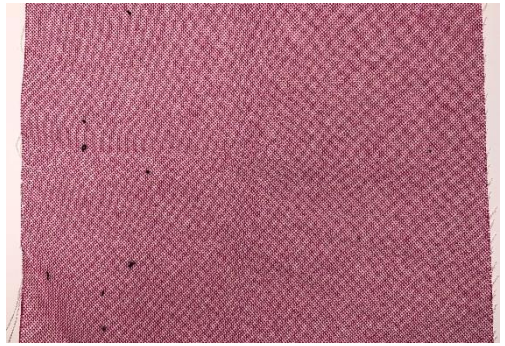


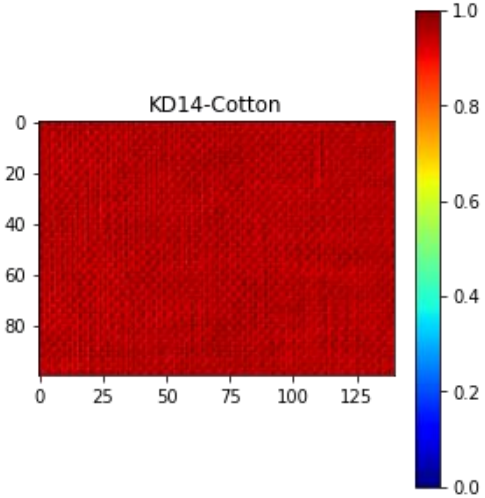
Cotton 74
Polyester 26

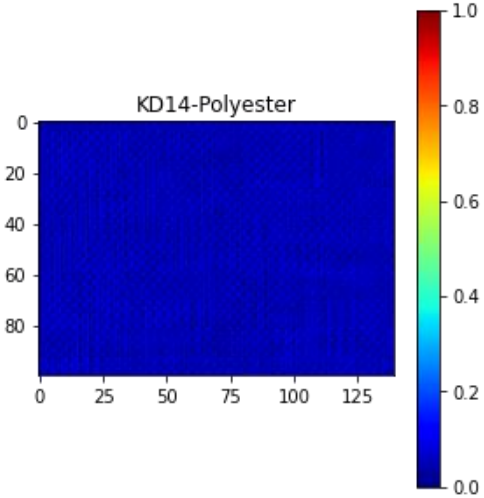
Cotton 74
Polyester 26

NIR LINEAR

Cotton 77
Polyester 23







Cotton 90
Polyester 10

Cotton 90
Polyester 10

NIR LINEAR

Cotton 95
Polyester 5

Photo credit : Refashion textiles library

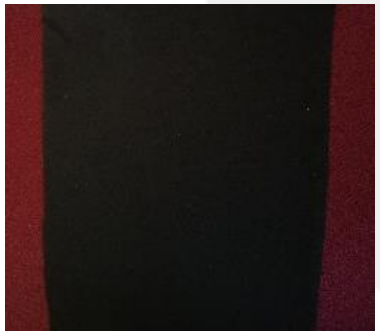
BLACK or DARK SAMPLES RESULTS (with NIR and SWIR)

Fibber type detection
SUCCESSFUL

Cotton / Elastane

Polyamide

Viscose



Cotton

Fibber type detection
UNSUCCESSFUL
- due to **BLACK CARBON** presence into the yarn

Polyamide

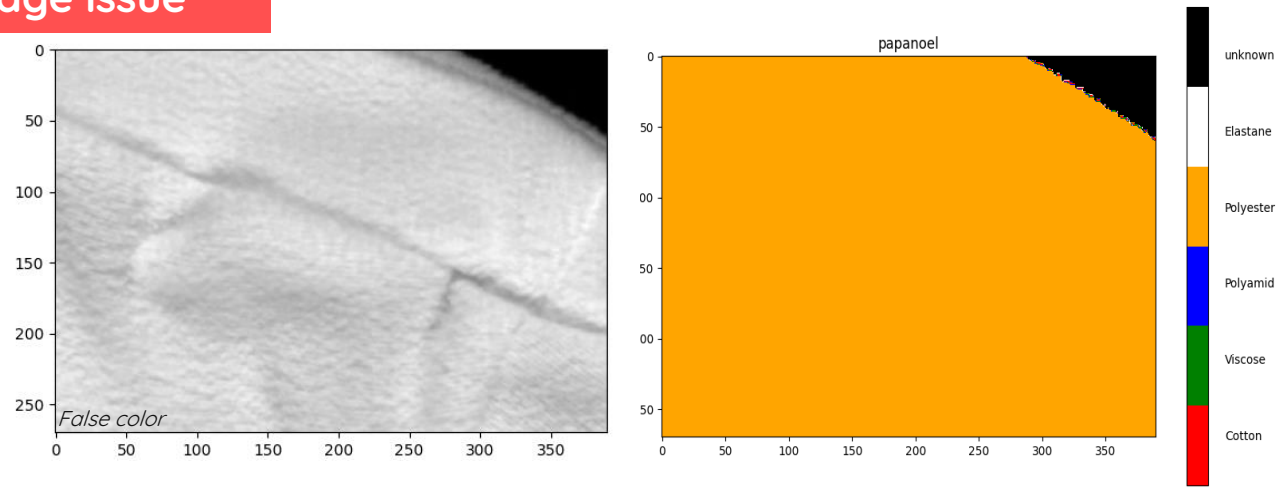
Fibber type detection
NOT ACURATE
- due to **VERY THIN LAYER** garment and dark colour

Cotton / Viscose

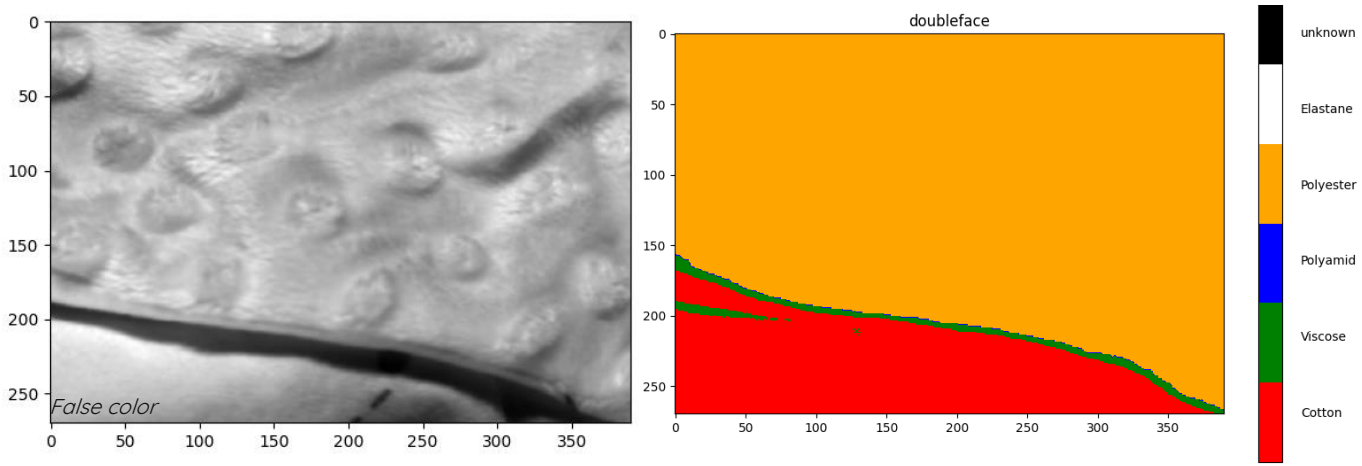
Photo credit : Refashion textiles library

POST CONSUMER TEXTILE TESTS & RESULTS

Edge issue



Double face



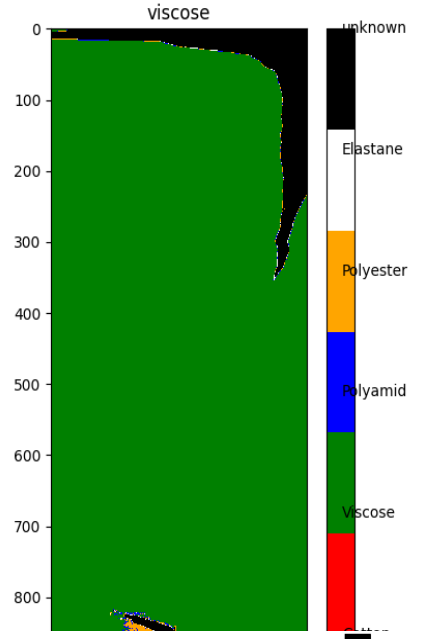
Embroidery

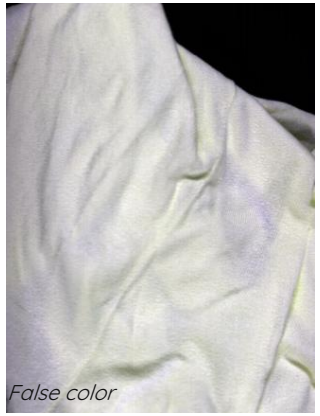
Photo credit : Ihab MAKKI - CEA PIMS Bordeaux

center

POST CONSUMER TEXTILE TEST & RESULTS

Garment anarchic positioning





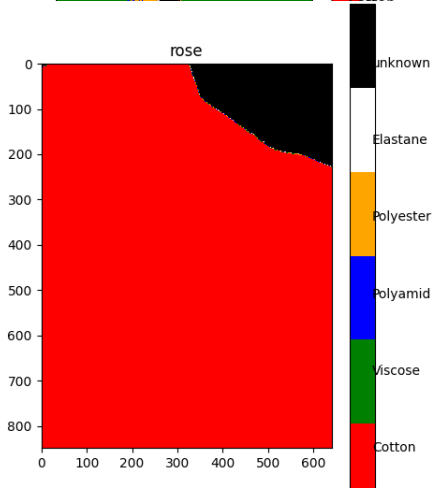
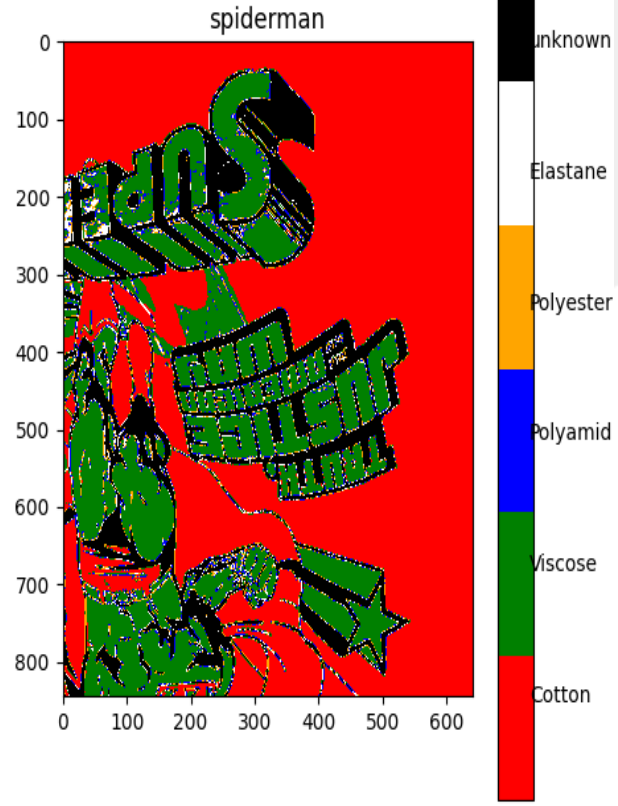


Photo credit : Ihab MAKKI - CEA PIMS Bordeaux

Print



CONCLUSION PERSPECTIVES

FIBER TYPE SORTING MAJOR KNOWLEDGES

COTON
ELASTANE

- Elastane has different spectrum than cotton and man made materials.
- The blend of Cotton/Elastane with low percentage of Elastane is difficult to characterize precisely as the elastane is commonly inserted into the cotton yarn.

POLYAMID
PA6 vs PA6.6

- The polyamide has a different spectrum than other materials which makes its identification possible.
- There was no clear difference between PA6 and PA6,6 in the 1200-1700 nm region. However it's work well into the extended SWIR system range (1700-2500nm).

COTON
VISCOSE

- Despite that the spectra of Cotton and Viscose are similar, the classification of the two materials is possible in the NIR range (1200-1700 nm)
- The study of blends showed that the quantification of the abundance of each material in each part of the sample is possible, and that it is possible to visualize the knitted fabric style.

COTON
POLYESTER

- The estimation of blend cotton/ Polyester is possible in the NIR region. No need of SWIR.

BLACK

- Some dark or black textiles can be classified in the NIR range (1200-1700nm)
- Dark or black sample, having black Carbon in their composition, will require MWIR range imager

MISTERY PROJECT 5 MAJOR LEARNINGS

1. LINEAR NIR **HYPERSPECTRAL** (900nm to 1700nm) system allow **BETTER** and **FASTER** quality detection of principal studied garment field (Cotton, Polyester, Polyamid, Viscose, blended…) than actual dot hyperspectral NIR system

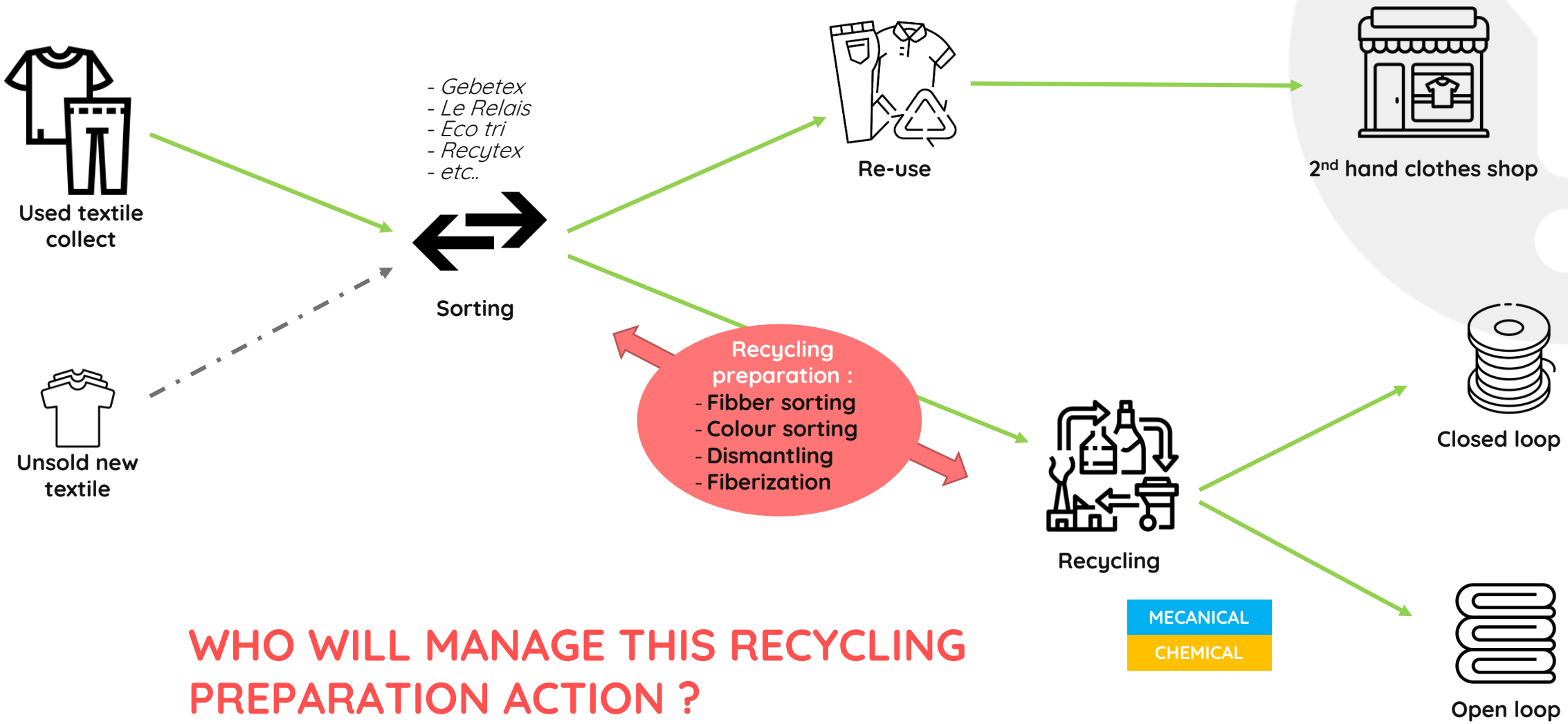
2. SWIR **HYPERSPECTRAL** (1700 to 2500nm) **system add only the detection of PA6 vs PA6.6** with good repeatability. However only 2 frequency in this range could do the job.

3. **ELASTANE STAY PROBLEMATIC** with NIR or SWIR hyperspectral system to detect quantitatively due to its composition into the yarn. One solution could be to pre-process the garment (cutting, fiberization etc…) before analyse it.

4. **BLACK** or **DARK GARMENT ARE SORTABLE in NIR or SWIR** like coloured or multi-coloured garment, if there composition is **OUT** (or with low percentage) **OF BLACK CARBON.** Otherwise it will require **MWIR** technology to identify fibber composition (if presence of Black carbon into it).

5. **GARMENT POSITIONING** is part of key success in textile sorting, but **LINEAR SCAN** technology **ALLOW MORE FLEXIBILITY** and **ACCURACY** than dot scan technology (better view of garment border, garment overlay, double face if both are visible, small prints, embroidery, etc…)

TEXTILE INDUSTRIE QUESTION



WHO WILL MANAGE THIS RECYCLING PREPARATION ACTION ?

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LEARNING GUIDE

NIR & SWIR HYPERSPECTRAL LINE SCAN IMAGER FOR AUTOMATIC TEXTILE SORTING

Photo credit : GEBETEX

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