

## Project Report

# „Mechanical batch sorting test at pilot NIR-line“

### 1. Task Definition

To help the City of Copenhagen (and other actors) prepare for the Danish 2023-2025 requirements for separate collection of household waste textiles, there is a need for sustainable and innovative treatment solutions for a whole new waste stream.

The waste textiles being examined in this project, are comparable to the definition of textile waste, that the Danish Environmental Protection Agency recently has send for public consultation.

A delivery of post-consumer waste textiles originating from households in the City of Copenhagen and Vestforbrænding (Rødovre), is to be visually separated into reusable and recyclable categories. Both fractions are then to be analyzed respectively by means of the NIR pilot textile sorting system and sorted into 17 defined material classes.

### 2. Visual Quality Sorting

The client delivered a total of 13 bales of textile waste with a total weight of about 4900 kg to SOEX on 09/07/2021. 12 bales were opened one by one and the contained waste was removed. The remaining clothing was then sorted by sorting personnel with respect to quality into the category's "reusable" (directly sellable) and "recyclable".

### 3. Determination of Material Composition by NIR Textile Sorting System

For the spectroscopic examination of the textiles, a multiplexing NIR spectrometer of the type LLA Instruments uniSPEC2.2MPL (serial number: M814-18) was used, which is connected to the associated illumination unit PMAmpl1400 as well as the lens bar OpticLine OL1400 by means of a mounting bridge to form a fixed unit. This unit is arranged above a black rubber conveyor belt driven by an electric motor. The textiles were placed in a single layer on the conveyor belt by an employee and moved under the OpticLine at a defined adjustable speed. The radiation reflected by the textiles is analysed spectrally and the corresponding measurement data is stored digitally. At the end of the sorting line, a monitor is attached on which the analysis result is displayed. A second employee picks up the textile at the end of the conveyor belt and throws it into provided collection bins, which are labelled with the 17 agreed categories. The schematic layout of the measuring arrangement is shown in figures A.1 and A.2 in the appendix.

During the automatic sorting we noticed that for some textiles only very weak and noisy reflection spectra resulted, in which only the structure of one main absorption band can be evaluated. This effect mainly affected medium grey or black dyed textiles made of cotton or polyester. The reason for this is presumably black colour pigments based on carbon, which absorb a major part of the NIR radiation. For this type of textiles, the additional category 18 "low spectral signal" was introduced.

Furthermore, there were also textiles that either did not reflect NIR radiation or could not be identified by the analysis method. In the first case, these are black-dyed textiles that absorb all NIR radiation due to a high amount of black carbon-containing colour pigments. In the second case, these are textile fabrics coated with PP or PVC for which the analysis method has not yet been trained. This type of textile was grouped together as the category "not identifiable".

## 4. Results

The following tables 1 to 3 show the results of the material analysis for the wearable textiles, the non-wearable textiles and the waste. The composition of the total delivery including the textiles not identifiable by NIR spectroscopy is shown in Table 4.

Table 1: Material composition of wearable textiles.

Category	Material	Weight in kg	Percentage
1	100% Cotton	48.2	19.3
2	100% Viscose	8.5	3.4
3	100% Polyester	48.1	19.2
4	100% Polyamide	1.7	0.7
5	100% Acrylic	3.0	1.2
6	100% Wool	4.7	1.9
7	Polyester-cotton-blend, cotton content < 20%	1.5	0.6
8	Polyester-cotton-blend, polyester content < 20%	6.1	2.4
9	Polyester-cotton-blend, other proportions	13.0	5.2
10	Polyester-viscose-blend, viscose content < 20%	1.0	0.4
11	Polyester-viscose-blend, polyester content < 20%	0.6	0.2
12	Polyester-viscose-blend, other proportions	7.3	2.9
13	Polyester-elastane-blend	1.7	0.7
14	Polyamide-blends	23.9	9.6
15	Acrylic-wool-blend	0.2	0.1
16	Acrylic-cotton-blend	2.6	1.0
17	Other material	56.9	22.8
18	Low spectral signal	21.1	8.4
<b>Total</b>		<b>250.1</b>	<b>100.0</b>

Table 2: Material composition of non-wearable textiles.

Category	Material	Weight in kg	Percentage
1	100% Cotton	913.0	28.5
2	100% Viscose	59.0	1.8
3	100% Polyester	401.0	12.5
4	100% Polyamide	21.3	0.7
5	100% Acrylic	36.7	1.1
6	100% Wool	69.7	2.2
7	Polyester-cotton-blend, cotton content < 20%	15.4	0.5
8	Polyester-cotton-blend, polyester content < 20%	101.2	3.2
9	Polyester-cotton-blend, other proportions	210	6.5
10	Polyester-viscose-blend, viscose content < 20%	12.2	0.4
11	Polyester-viscose-blend, polyester content < 20%	12.0	0.4
12	Polyester-viscose-blend, other proportions	73.6	2.3
13	Polyester-elastane-blend	126.0	3.9
14	Polyamide-blends	266.6	8.3
15	Acrylic-wool-blend	20.5	0.6
16	Acrylic-cotton-blend	24.3	0.8
17	Other material <sup>*)</sup>	579.2	18.0
18	Low spectral signal	267.4	8.3
<b>Total</b>		<b>3209.1</b>	<b>100.0</b>

<sup>\*)</sup> This fraction is divided into 71.8% other material and 28.2% cotton with imprints or coatings.

Table 3: Material composition of waste.

Material	Weight in kg	Percentage
Shoes	472.0	43.7
Textile waste	195.5	18.1
Feathers	140.0	13.0
Municipal waste	106.5	9.9
Bags	81.1	7.5
Electronic waste	28.0	2.6
Metal	23.0	2.1
Paper/ cardboard	15.0	1.4
Foils	13.5	1.2
Carpets	3.1	0.3
Plastic	3.0	0.3
<b>Total</b>	<b>1080.7</b>	<b>100.0</b>

Table 4: Composition of the total delivery.

Fraction	Weight in kg	Percentage
Waste	1080.7	23.6
Textiles wearable	250.1	5.4
Textiles non-wearable	3209.1	70.2
Not identifiable	32.7	0.70
<b>Total</b>	<b>4572.6</b>	<b>100.0</b>

In the annex there is a collection of photos of selected textiles of categories 1 to 17 (see figures A.3 to A.53). The additionally introduced category 18 "Low spectral signal" (see figures A.54 to A.58) as well as the category "not identifiable" (see figures A.59 to A.62). Figures A.63 to A.73 show the different types of waste.

## 5. Reuse and Recycling of Textile Waste

There are three options in reuse and recycling after processing the non-wearable textiles in our company. Firstly, the reuse of mainly cotton-containing waste as absorbent wipers. Secondly, the material recycling as torn fibre in the automotive industry (moulded parts, covers), textile industry (clothing, carpets), construction industry (fleeces, insulation material) and paper production. Categories 5 (100% Acrylic), 6 (100% Wool), and 15 (Acrylic-wool-blend) are particularly interesting for the textile industry. Thirdly, chemical recycling of textiles sorted by material from categories shown in table 5.

Table 5: Categories suitable for chemical recycling.

Category	Material
1	100% Cotton
2	100% Viscose
3	100% Polyester
4	100% Polyamide
7	Polyester-cotton-blend. cotton content < 20%
8	Polyester-cotton-blend. polyester content < 20%
10	Polyester-viscose-blend. viscose content < 20%
11	Polyester-viscose-blend. polyester content < 20%
14	Polyamide-blends

## Annex



Figure A.1: Side view of the NIR-sorting line.



Figure A.2: End of the NIR-sorting line with display of the identified material type.



Figure A.3: Selected textiles of category 1 (100% cotton).



Figure A.4: Selected textiles of category 1 (100% cotton).



Figure A.5: Selected textile of category 1 (100% cotton).



Figure A.6: Selected textiles of category 2 (100% viscose).



Figure A.7: Selected textile of category 2 (100% viscose).



Figure A.8: Selected textiles of category 3 (100% polyester).





Figure A.9: Selected textiles of category 3 (100% polyester).



Figure A.10: Selected textile of category 3 (100% polyester).



Figure A.11: Selected textiles of category 4 (100% polyamide).



Figure A.12: Selected textiles of category 4 (100% polyamide).



Figure A.13: Selected textiles of category 4 (100% polyamide).



Figure A.14: Selected textiles of category 5 (100% acrylic).



Figure A.15: Selected textiles of category 5 (100% acrylic).



Figure A.16: Selected textiles of category 6 (100% wool).



Figure A.17: Selected textile of category 6 (100% wool).



Figure A.18: Selected textiles of category 6 (100% wool).



Figure A.19: Selected textiles of category 7  
(Polyester-cotton-blend. cotton content < 20%).



Figure A.20: Selected textile of category 7  
(Polyester-cotton-blend. cotton content < 20%).



Figure A.21: Selected textile of category 7  
(Polyester-cotton-blend. cotton content < 20%).



Figure A.22: Selected textile of category 7  
(Polyester-cotton-blend. cotton content < 20%).



Figure A.23: Selected textiles of category 8  
(Polyester-cotton-blend. polyester content < 20%).



Figure A.24: Selected textiles of category 8  
(Polyester-cotton-blend. polyester content < 20%).





Figure A.25: Selected textile of category 8  
(Polyester-cotton-blend. polyester content < 20%).



Figure A.26: Selected textile of category 9  
(Polyester-cotton-blend. other proportions).



Figure A.27: Selected textiles of category 9  
(Polyester-cotton-blend. other proportions).



Figure A.28: Selected textile of category 9  
(Polyester-cotton-blend. other proportions).



Figure A.29: Selected textile of category 10  
(Polyester-viscose-blend. viscose content < 20%).



Figure A.30: Selected textile of category 10  
(Polyester-viscose-blend. viscose content < 20%).



Figure A.31: Selected textiles of category 10  
(Polyester-viscose-blend. viscose content < 20%).



Figure A.32: Selected textile of category 11  
(Polyester-viscose-blend. polyester content < 20%).



Figure A.33: Selected textile of category 11  
(Polyester-viscose-blend. polyester content < 20%).



Figure A.34: Selected textile of category 11  
(Polyester-viscose-blend. polyester content < 20%).



Figure A.35: Selected textiles of category 12  
(Polyester-viscose-blend. other proportions).



Figure A.36: Selected textile of category 12  
(Polyester-viscose-blend. other proportions).



Figure A.37: Selected textiles of category 12  
(Polyester-viscose-blend. other proportions).



Figure A.38: Selected textiles of category 13 (Polyester-elastane-blend).



Figure A.39: Selected textile of category 13 (Polyester-elastane-blend).



Figure A.40: Selected textiles of category 13 (Polyester-elastane-blend).





Figure A.41: Selected textile of category 14 (Polyamide blends).



Figure A.42: Selected textiles of category 14 (Polyamide blends).



Figure A.43: Selected textiles of category 14 (Polyamide blends).



Figure A.44: Selected textiles of category 15 (Acrylic-wool-blends).



Figure A.45: Selected textiles of category 15 (Acrylic-wool-blends).



Figure A.46: Selected textile of category 16 (Acrylic-cotton-blends).



Figure A.47: Selected textile of category 16 (Acrylic-cotton-blends).



Figure A.48: Selected textile of category 16 (Acrylic-cotton-blends).



Figure A.49: Selected textiles of category 17 (Other material).



Figure A.50: Selected textiles of category 17 (Other material).



Figure A.51: Selected textiles of category 17 (Other material).



Figure A.52: Selected textiles of category 17 (Other material).



Figure A.53: Selected textiles of category 17 (Other material).



Figure A.54: Selected textile of category 18 (Low spectral signal).



Figure A.55: Selected textile of category 18 (Low spectral signal).



Figure A.56: Selected textile of category 18 (Low spectral signal).





Figure A.57: Selected textile of category 18 (Low spectral signal).



Figure A.58: Selected textile of category 18 (Low spectral signal).



Figure A.59: Selected textiles of category "Not Identified" (No analysable signal).



Figure A.60: Selected textile of category "Not Identified" (No analysable signal).



Figure A.61: Selected textiles of category "Not Identified" (No analysable signal).



Figure A.62: Selected textile of category "Not Identified" (No analysable signal).



Figure A.63: Non-textile waste (472.0 kg shoes of total 1080.7 kg waste).

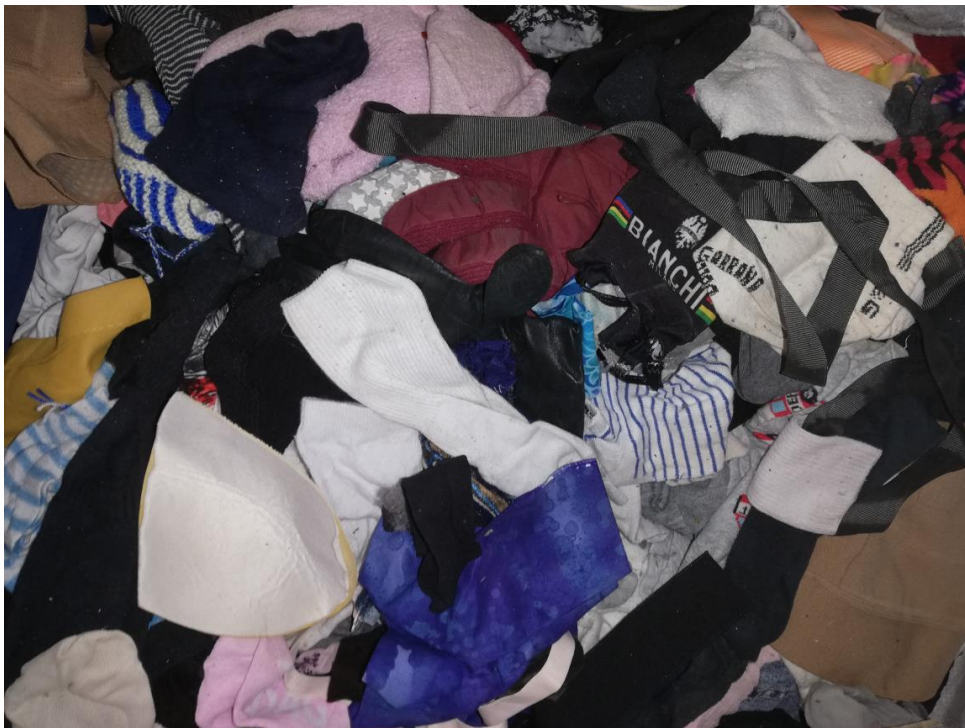


Figure A.64: Textile waste (195.5 kg textiles of total 1080.7 kg waste).



Figure A.65: Non-textile waste (140.0 kg feathers of total 1080.7 kg waste).



Figure A.66: Non-textile waste (106.5 kg municipal waste of total 1080.7 kg waste).





Figure A.69: Non-textile waste (23.0 kg metal of total 1080.7 kg waste).



Figure A.70: Non-textile waste (15.0 kg paper/ card board of total 1080.7 kg waste).



Figure A.71: Non-textile waste (13.5 kg foils of total 1080.7 kg waste).



Figure A.72: Non-textile waste (3.1 kg carpets of total 1080.7 kg waste).





Figure A.73: Non-textile waste (3.0 kg plastic of total 1080.7 kg waste).