USING NIR TECHNOLOGY TO IDENTIFY VALUE IN WASTE TEXTILE STREAMS

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EXTENDED ABSTRACT

Key Words: Circular economy, NIR spectrometry, Waste textile streams

1. INTRODUCTION

Textile waste consists of different organic polymeric materials. Each textile material type has different characteristics that have an effect on which recycling processes they are most suitable for. For example, chemical recycling processes typically have high purity requirements, even up to 100%. Blends and especially elastane may interfere with the chemical reactions used in chemical recycling, but they affect mechanical recycling as well. Using current technologies, homogenous fabrics are the easiest to recycle.

The European Union has announced a new directive that requires textile waste to be collected separately, which will come into effect 1st of January 2025. Current textile waste streams are 72 000 t in Finland [1], over 300 000 t in the Nordic countries [2] and 5 800 000 t in the EU [3]. Sorting textile waste based on its fibre composition increases the value of the textile waste as a secondary raw material. In Finland, the roadmap for recycled textiles in the 2020's aims to reduce the incineration of textile waste (Figure 1) [4]. To replace incineration, the focus is on creating new business using circular economy guidelines, where "waste" is given new life. The drivers behind this approach come from global megatrends.

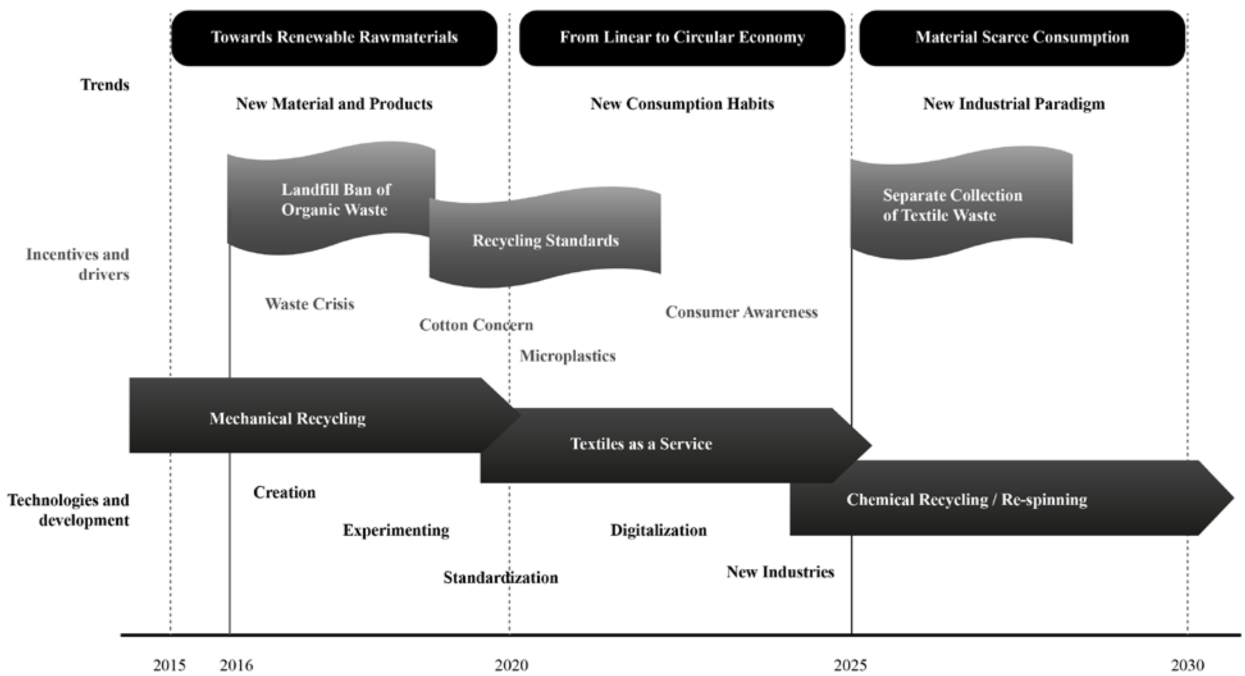

Figure 1. Roadmap for recycled textiles in Finland in the 2020´s [4]

It is estimated that in Finland, by 2030, the incineration of textile waste could be reduced to 8 000 t and that 87 000 t of textiles could be recycled yearly. In this scenario, chemical recycling

would increase to 35 000 tonnes [4]. An example of this in action is the Infinited Fiber Company whose aim is to turn textile waste to new natural fibre. [5]
Sorting waste streams manually is laborious, slow and unreliable as recognition of textile fibres is based on washing label information and/or the sorters' own hands-on experience. Replacing manual sorting with automated, optical material recognition allows more efficient and more reliable sorting, and minimises the risks of clogging and contamination in recycling processes, be they mechanical or chemical. Our main aim is to automatically identify and sort fibres from the kinds of textile waste streams (both pre- and post-consumer) that are currently unusable and would otherwise end up in incineration or landfill.

2. MATERIALS AND METHODS

Textiles consist of organic compounds that can be recognised by their absorption of energy in the NIR (near infra red) wavelength range, especially between 1100-1650 nm and 2000-2300 nm. NIR is widely used in industry as it provides a quick and safe method for spectral analysis, as no sample preparation is required and measurement can be contactless. There are other methods for textile identification but they are usually laboratory measurements, slow or degrade sample materials (i.e., chromatography).

As a part of larger scale textile recycling research, a quick method for fibre recognition was developed. The REISKAtex® method involves spectral library construction, optimisation of spectral pre-treatment methods and mathematical pattern recognition. Our REISKAtex® sorting line identifies unknown textile fibres in textiles by comparing their spectrum to a known material spectral library and then sorts the identified textiles using automated air blowers. The libraries have been built using verified textile fibre samples. The samples originated from fabric manufacturers and the composition of the fibres was labelled by the manufacturers. An FT-IR analyser with a commercial spectral library was used to double-check the recognition of the samples before feeding them into the sorting line. Finally, the measurements were cross-referenced to filter outliers.

Natural variations in fibres and their physical properties (e.g. density and thickness, weave structure) in textiles has a slight effect on the NIR spectrum. Therefore, the REISKAtex® recognition algorithm has been set to allow a certain threshold of difference between the sample and its equivalent library spectra. The optimal algorithms for a wider range of material identification can be set when needed, but will lower the purity level of the sorted textiles.

3. RESULTS AND DISCUSSION

The REISKAtex® sorting line is currently set to sort out 100% cotton, 100% polyester, 100% wool, 100% viscose and some common CO/PES blends from a heterogeneous textile waste stream. A test run was carried out for 300 kg of discarded post-consumer textiles including garments and household textiles that were either unlabelled or otherwise unrecognisable or non-re-sellable. The REISKAtex® line sorted 100% pure fractions as follows: 35% cotton, 6% polyester and 0.5% wool. Re-examination of these samples and a random selection from pure samples, with FT-IR, revealed that less than 0.8% were misidentified or contained impurities (e.g. elastane). This indicates high sorting accuracy. The recognition algorithms can be further tuned to allow slight impurities (i.e. blends) if higher yields with lower purity requirements are desirable. Alternatively, deviation thresholds can be tightened to identify only very pure materials with lower output yields. Strict thresholds could also be used to sort different textile blends from each other but spectra libraries using a larger number of textile blend samples need to be built to enable this.

Detection of elastane, however, has proven to be difficult as most garments contain only a few percent of it. Furthermore, it is usually integrated into the core of the fibre. As NIR measurement operates on the materials' surface level only, detection is, at least partially, affected by the depth at which the elastane is located and it is dependent on the weave structure of the sample.

At the moment, the REISKAtex® sorting line's capacity is approximately 100 kg/h of textiles, limited by manual feeding and quality assurance. The spectral measurement and recognition itself only takes about 10-20 ms. With slight alterations to the line, it is possible to increase the line speed to match typical manual sorting lines, where four manual sorters go through 1000 kg of textiles in an hour. The manual feeding currently used for the sorting line leaves a required gap between each sample and allows smooth automation. Re-arrangement of the sensors and optimising the timing of the machinery for faster feeding could, however, be achieved.

4. CONCLUSIONS

The REISKAtex® sorting line is currently set to separate 100% cotton, 100% polyester, 100% wool, 100% viscose, in addition to common CO/PES blends, from a heterogeneous textile waste stream. Its ability to identify and separate textiles with high accuracy was proven in this experiment. Separation of different compositions of CO/PES blends from each other looks promising, but needs further development.

In conclusion, using NIR technology is an efficient way to identify value in discarded textiles. In further studies, attention should also be paid to getting more understanding about which textile fibres would bring the most value and developing the REISKAtex® sorting line's capability accordingly.

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