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END-OF-LIFE MANAGEMENT: LCA OF TEXTILE WASTE RECYCLING

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ABSTRACT

Textile and apparel consumption is increasing because of global population growth and higher living standards. In Sweden, approximately 130,000 tonnes of textiles are consumed annually and end up as waste. This paper describes a preliminary investigation of textile recycling techniques which can potentially replace incineration - the dominant waste management method in Sweden. Life cycle assessment is performed to explore the potential environmental benefits of the textile recycling techniques. The investigated recycling processes are: remanufacturing, separation of cellulose from polyester using N-methylmorpholine-N-oxide; and chemical polyester recycling. The results show that incineration has the highest global warming potential and primary energy usage of compared alternatives. The other options thus seem to be promising alternatives since they also replace products from primary resources.

INTRODUCTION

Global population growth and improvements in living standards have caused an increase in the production and consumption of textiles during the past few decades (Wang, 2006) Furthermore, the accelerating fashion cycle results in more frequent replacement of the products with fresher and more modern goods which in turn results in generation of more textile waste (Fletcher, 2008).

In Sweden, the predominant method of textile waste treatment is incineration. Presently, a lack of recycling techniques that have proven to be cost-effective at full scale and the existence of cheap fabrics on the market, limit the interest in recycling. Moreover, the large variety of fibers and colours used in fabrics are considered limiting factors in textile recycling, since they challenge the sorting processes and decrease the quality of recycled materials (Palm, 2011).

However, new technologies for recycling textile waste are being developed. Chemical approaches for textile recycling include dissolution and separation of cellulose from polyester

by using N-methylmorpholine-N-oxide (NMMO) (Jeihanipour, Karimi, Niklasson, & Taherzadeh, M, 2010) and degradation of polyester to dimethyl terephthalate (DMT) for repolymerization and spinning new polyester fibre (Patagonia Inc., 2011).

METHODS

This paper reports on an environmental life cycle assessment (LCA) that was performed to quantify the energy usage and climate change impact of different emergent textile recycling technologies.

Functional unit

The functional unit used in the calculations is 'waste treatment for one tonne of household textile waste' by each technique. The model waste considered in this study is discarded household textiles, consisting of 50% cotton and 50% polyester.

System boundaries and description of the technical systems

The environmental impacts are assessed from the moment where the collected textile waste enters the recycling facilities until treatment of the residues generated in each recycling system and the use of by-products have been accounted for. All the recycling technologies and the entry on the market of the new products are assumed to be located in Sweden. In order to correct for differences in functions between the systems, system expansions (substitutions) are applied for products and by-products. In the expanded system, manufacturing of textile fibers and products from primary resources are assumed to take place in China.

Energy recovery

Incineration with energy recovery is the dominant textile waste treatment technology in Sweden. The technology considered is a combined heat and power incineration plant with advanced flue gas treatment based on the SWEA model (Palm & Ljunggren Söderman, 2010).

Material reuse

Remanufacturing is the practice of taking reusable textile waste material and transforming it into a new product. In this process, the whole collected textile waste flow is first washed and dried. Afterwards, reusable textile pieces with high enough quality are separated manually, cut, and sent to a sewing machine for manufacturing of new products. Manufacturing of textile bags is considered because it is a simple pattern for which relatively small pieces of textile are needed. The textile residue from cutting and the unused textile waste is sent to incineration.

Separation of cellulose from polyester using NMMO solvent

In this process, NMMO is mixed with the textile waste. The cellulose fraction dissolves, and the solution is pumped through filters to separate the cellulosic solution from the polyester which remains undissolved. The remaining polyester is assumed to be in a form that makes it possible to direct to spinning machines; 100% of the remaining polyester is assumed to be recovered by twisting and extending the fibers and turning them to yarns. The solution of NMMO and cellulose, is forced through showerhead spinners where long strings of fibers come out through small holes. The cellulosic fibers are washed and yarns can be freed from NMMO by passing through a washing process and finally, water is removed by drying (Shen & Patel, 2010) (Shen, Worrell, & Patel, 2010).

Recycling of polyester

In this process, discarded garments and fabrics of polyester are first separated manually from the rest of the textile waste. They are then cut into smaller pieces and further broken down until only small granules remain. A reaction with a chemical is employed to break the granules down into molecules of dimethyl terephthalate (DMT). Subsequently, DMT is chemically treated and polymerized to produce polyester granules, which are melted and spun into polyester yarns. It is assumed that 100% of the polyester is recovered in this process. The other 50% of the textile waste stream from the sorting step, i.e. all of the cellulosic material, is directed to incineration.

RESULTS: LIFE CYCLE IMPACT ASSESSMENT

A fuller description of this work is under review by a scientific journal. The total performance of the recycling systems per tonne of treated textile waste in terms of global warming potential and primary energy usage is illustrated in Figure 1. The black bar in each column represents a sensitivity analysis that was performed for each recycling technique. In the material reuse process, the yield was varied from 45% to either 20% or 70%, which greatly affects the results. For the cellulose/polyester separation process, the amount of thermal energy required for the dissolving step is assumed to be high. Therefore, it was varied by $\pm 50\%$, combined with a change of thermal energy source from natural gas to Swedish average district heat. Neither of these changes strongly affect the results. For the polyester recycling process, the amount of thermal energy required for the polymerization step was varied by $\pm 50\%$, combined with a change of thermal energy source from natural gas to Swedish average district heat. Neither change had an important effect.

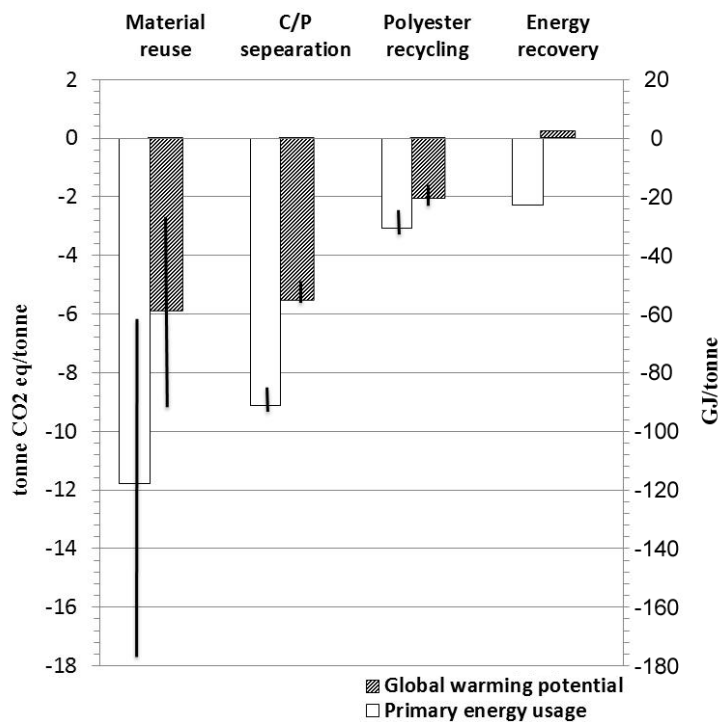


Figure 1: Comparison of environmental performance of textile waste management technologies in terms of net global warming potential and net primary energy usage, including results from sensitivity analysis illustrated by error bars

The dominant textile waste management option in Sweden, incineration, is seen to have the highest global warming potential and primary energy usage of the compared alternatives. The analysis shows that material reuse allows for considerable savings in global warming potential and energy usage, mainly due to the avoided production of a textile bag from primary resources. Both the polyester recycling and the cellulose/polyester separation processes, production of cellulose/polyester fibers from primary resources are energy intensive processes that strongly influence the savings that are possible for these technologies.

CONCLUSION

All of the emergent textile recycling technologies thus exhibited a more beneficial environmental performance than incineration also when some critical parameters were varied. This is an explorative LCA, the results are applicable only for a preliminary environmental assessment, since most of the data was based on either assumptions, literature data or was approximated with data from similar processes. However, the positive results indicate that textile recycling options should be studied in more detail in order to find out how to best reduce the environmental footprint of the textiles used in society.

REFERENCES

- Fletcher, K. (2008). *Sustainable fashion and textiles: design journeys*. London: Earth scan.
- Jeihanipour, A., Karimi, K., Niklasson, C., & Taherzadeh, M. J. (2010). A novel process for ethanol or biogas production from cellulose in blended-fibers waste textiles. *Waste Management*, 30(12), 2504-2509.
- Palm, D. (2011). Improved waste management of textiles. Retrieved from www.ivl.se/download/18.7df4c4e812d2da6a416800080103/B1976.pdf
- Palm, D., & Ljunggren Söderman, M. (2010). Bearbering och beräkning av data från modellen SWEA (In english: processing and calculation of data from SWEA model), *Stockholm*.
- Patagonia Inc. (2011). Patagonia's common Treads Garment Recycling Program: A detailed analysis. Retrieved from www.patagonia.com/pdf/en_US/common_threads_whitepaper.pdf
- Shen, L., & Patel, M. K. (2010). Life cycle assessment of man-made cellulose fibres. *World* (Vol. 88, pp. 1-59). Retrieved from http://igitur-archive.library.uu.nl/chem/2011-0401-200353/LB_88_2010_paper_1.pdf
- Shen, L., Worrell, E., & Patel, M. K. (2010). Open loop Recycling Environmental impact assessment of man-made cellulose fibres. "Resources, Conservation & Recycling", 55(2), 260-274. Elsevier B.V. doi:10.1016/j.resconrec.2010.10.001
- Wang, Y. (2006). *Textile recycling*. Cambridge: Woodhead Publishing Ltd.