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LCA SINGLE SCORE ANALYSIS OF MAN-MADE CELLULOSE FIBRES

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In this study, the LCA report "Life Cycle assessment of man-made cellulose fibres" [3] is extended to the single score analysis in order to provide an additional basis for decision making. The single score analysis covers 9 to 11 environmental impact categories. Three single score methods (Single Score I, II, and III) are introduced and applied. Single Score I assigns equal importance to all environmental impact categories and it does *not* apply normalisation. Single Score II also assigns equal importance to all impact categories and it *does* apply normalisation. Single Score III makes use of the normalised LCA results and combines them to a single score by application of the weighting factors developed by the Dutch Oil and Gas Exploitation and Production Association (Nederlandse Olie en Gas Exploitatie en Productie Associatie, NOGEPA). All three single scores come to the conclusion that the four modern man-made cellulose fibres, namely Tencel Austria, Lenzing Modal, Lenzing Viscose Austria and Tencel Austria 2012, have the lowest overall impact among all studied fibres. According to both Single Score II and III, cotton has the highest impact; Lenzing Viscose Asia is similar to PET and both have higher impacts than PP.

Keywords: man-made cellulose fibre, LCA, single score, environmental impact assessment.

Introduction

Single score analysis is an optional step in a life cycle analysis according to the ISO guideline [1]. A single score analysis requires subjective opinions in order to weight the relative importance of different environmental impact categories. The subjective views are represented by (quantitative) weighting factors, which represent the relative importance of different environmental impacts and are used to calculate one single, aggregated value (single score). A single score analysis is used to support decision making, especially when it is difficult to have an overall conclusion merely based on mid-point results [2].

The purpose of this report is to conduct a single score analysis based on the cradle-to-factory gate mid-point results of the LCA study "Life Cycle assessment of man-made cellulose fibres" [3]. The LCA study was reported complying strictly with the ISO standards (i.e., it is an ISO-audited report), according to which single score must not be presented [1]. In this report, we use single score methods in order to draw an overall conclusion from the LCA study. This report does not comply with the ISO requirements but it is peer-reviewed. The potential readers of this report include the fibre industry, textile and nonwoven industry, policy makers, NGOs, as well as LCA practitioners.

Method to calculate single score results

In this study, three single score indicators are introduced. Single Score I and II are based on equal weighting factors among different environmental themes. Single Score III is based on a set of weighting factors determined by NOGEPA (Dutch Oil and Gas Exploitation and

Production Association). All three single scores are calculated based on the mid-point results reported as the baseline results in [3] (section on page 28 to 35). The compared fibre types are Lenzing man-made cellulose fibres, i.e., Lenzing Viscose Asia, Lenzing Viscose Austria, Lenzing Modal, Tencel Austria and Tencel Austria 2012, and other commodity fibres, i.e. conventional cotton (US & CN), PET (Western Europe) and PP (Western Europe) [3].

Single Score I

In Single Score I, it is assumed that all the environmental categories are of the same importance. The score is directly derived from the mid-point results (or the characterisation results). As a reference, the score of cotton is set to 100. No normalisation step is applied. The calculation can be illustrated by the following formula:

$$SingleScoreI_i = \sum_j \left(\frac{E_{i,j}}{E_{COTTON,j}} \times 100\% \times W_j\right) \qquad \text{Equation (1)}$$

In which:
i represents the fibre type;
j is the environmental theme (e.g., abiotic depletion, eutrophication, etc.);
E is the mid-point result of the environmental impact (in kg substances equivalent/tonne fibre);
W is the weighting factor, which is a constant value (=1) for each environmental theme for this single score.

In Single Score I, the environmental themes included are the CML baseline indicators plus land use and water use. The CML baseline method includes the global warming potential for a time period of 100 years (GWP100a), abiotic depletion, ozone layer depletion, human toxicity, fresh water aquatic ecotoxicity, terrestrial ecotoxicity, photochemical oxidant formation, acidification and eutrophication. Marine aquatic ecotoxicity is excluded because the characterisation factors are subject to substantial uncertainties [4]. The energy indicators (NREU, non-renewable energy use) are also excluded from this single score, because the depletion of non-renewable resources has already been taken into account in the indicator "abiotic depletion".

Single Score II

Similar to Single Score I, Single Score II assumes that all the environmental impact categories are of the same importance. The mid-point results are, however, divided by the normalisation factors (World 2000) [5] before the total scores are added up. Again, the score of cotton is set to 100 for comparison. Single Score II is calculated by the following formula:

$$SingleScoreII_i = \frac{\sum_j \left(\frac{E_{i,j}}{N_j} \times W_j\right)}{\sum_j \left(\frac{E_{COTTON,j}}{N_j} \times W_j\right)} \times 100\% \qquad \text{Equation (2)}$$

In which:
i is the type of fibre;
j is the environmental theme (e.g., abiotic depletion, eutrophication, etc.);
E is the mid-point result of the environmental impact (in kg substances equivalent/tonne fibre);
N is the normalisation factors [5] (in kg substances equivalent);
W is the weighting factor, which is a constant value (=1) for each environmental theme for this single score.

Single Score II includes the environmental impact categories of the CML baseline method. Water use and land use are excluded because the normalisation poses data problems and methodological problems[1].

Single Score III

Single Score III is calculated in a similar way as Single Score II by means of Equation (2), except that the NOGEPA weighting factors are taken into account, as shown in Table 1. It should be noted that this set of weighting factors represent the opinion of the Dutch oil and gas industry. Climate change is hence the most important environmental issue from the energy sector's point of view. It is, however, not a given that the fibre industry agrees with the weighting factors proposed by the energy industry. We nevertheless use this set of weighting factors because the opinions from the fibre industry are not available; moreover, it is important for us to understand how the LCA scores when climate change is considered to be the most important environmental impact category.

Table 1. NOGEPA weighting factors for the CML environmental impact categories [6].

Environmental theme [1,2]	Weight
Climate Change	32
Ozone layer depletion	5
Abiotic depletion	8
Human toxicity	16
Fresh water ecotoxicity	6
Terrestrial ecotoxicity	5
Photochemical oxidation	8
Acidification	6
Eutrophication	13
Total	**99**

Note: 1. Abiotic depletion is not weighted by NOGEPA, we add it in because we consider it to be an important environmental theme in this study.
2. Marine aquatic ecotoxicity is not included in this study and thus not listed in this table. It is, however, weighted as 8 by the NOGEPA.

Single score results

Single Score I

The result of Single Score I is shown in Figure 1. The assumption underlying Single Score I is that all environmental categories are of the same importance. No normalisation step is carried out for this single score. The relative environmental impacts are calculated by setting cotton as the reference. In Figure 1, it is shown that for cotton, each environmental impact weighs the same and the total impact is indexed as 100. The data on environmental impacts are taken from the cradle-to-factory gate mid-point results [3]. Lenzing Viscose Asia is comparable with cotton. The most important environmental impacts of Lenzing Viscose Asia are photochemical oxidation, abiotic depletion, GWP and ozone layer depletion (Figure 1).

[1] So far no suitable methods are available to aggregate the impact of different types of land and water. The normalisation factors, which represent the aggregated global impacts of land use and water use, are not available.

Single Score II

Figure 2 shows the result of Single Score II (cotton=100). Single Score II comes to a different conclusion than Single Score I in terms of the ranking between cotton and Lenzing Viscose Asia. Here, cotton has the highest score due to its very high normalised impacts on ecotoxicities. The fresh water ecotoxicity and terrestrial ecotoxicity of cotton account for 70% and 20% of the single score of cotton, respectively. Lenzing Viscose Asia is ranked as the second least favourable choice by Single Score II. It has only 9% of the score of cotton and has a slightly higher score than PET. PP fibre scores about 2/3rd of Lenzing Viscose Asia and 5% of cotton. The other four man-made cellulose fibres, namely Tencel Austria, Lenzing Modal, Lenzing Viscose Austria and Tencel Austria 2012, have very low scores compared to cotton (less than 5% of cotton's score, see Figure 2).

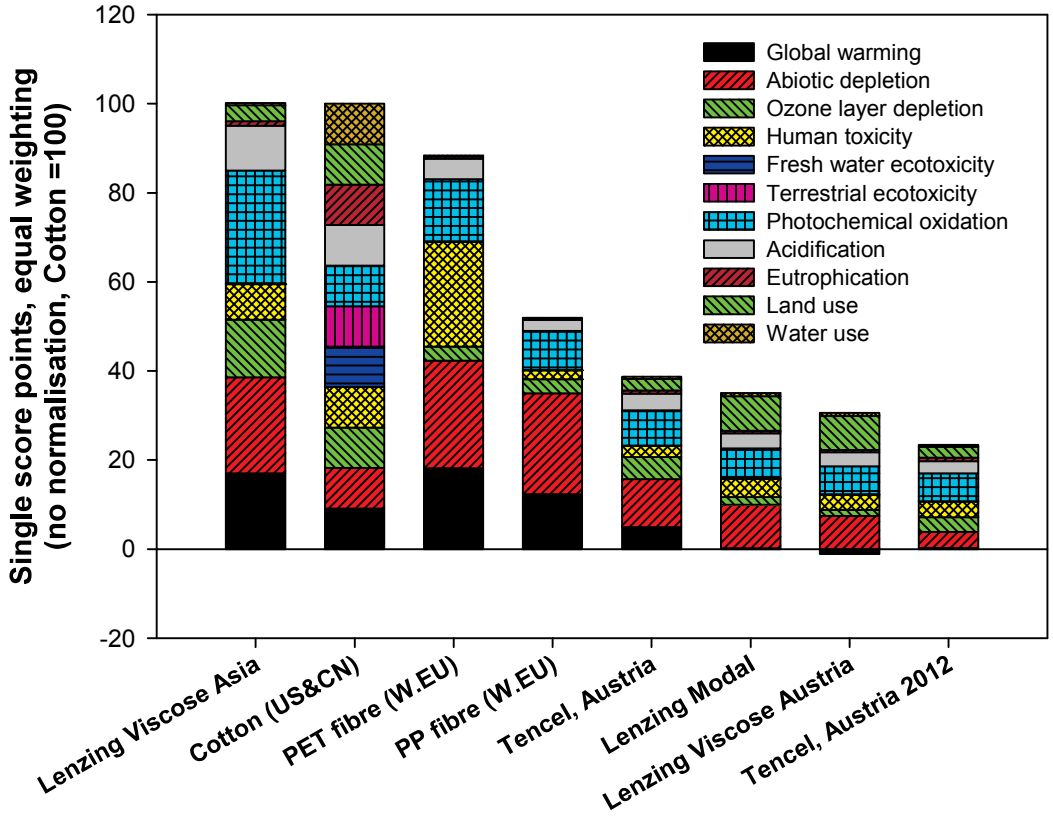

Figure 1. Single Score I, cradle-to-factory gate, no normalisation, equally weighted eleven environmental impact categories (cotton =100).

Single Score III

Both Single Score I and II assume equal weighting factors for all environmental categories. In reality some environmental problems are considered more important than others (by policy makers, by the public and by other stakeholders). Single Score III solves this problem by using the weighting factors established by NOGEPA. The result of Single Score III is shown in Figure 3. Single Score III shows a similar pattern as Single score II – cotton has the highest score. Although cotton is not an energy-intensive or greenhouse gas-intensive product, and global warming has the highest weighting factor according to NOGEPA, the scores from fresh water ecotoxicity and terrestrial ecotoxicity contribute approximately 90% of the single score of cotton. Unlike Single Score II, Single Score III leads to the result that Lenzing

Viscose Asia scores somewhat better than PET. Like the result from Single Score I and II, the other four man-made cellulose fibres, namely Tencel Austria, Lenzing Modal, Lenzing Viscose Austria and Tencel 2012, are the most favourable choices.

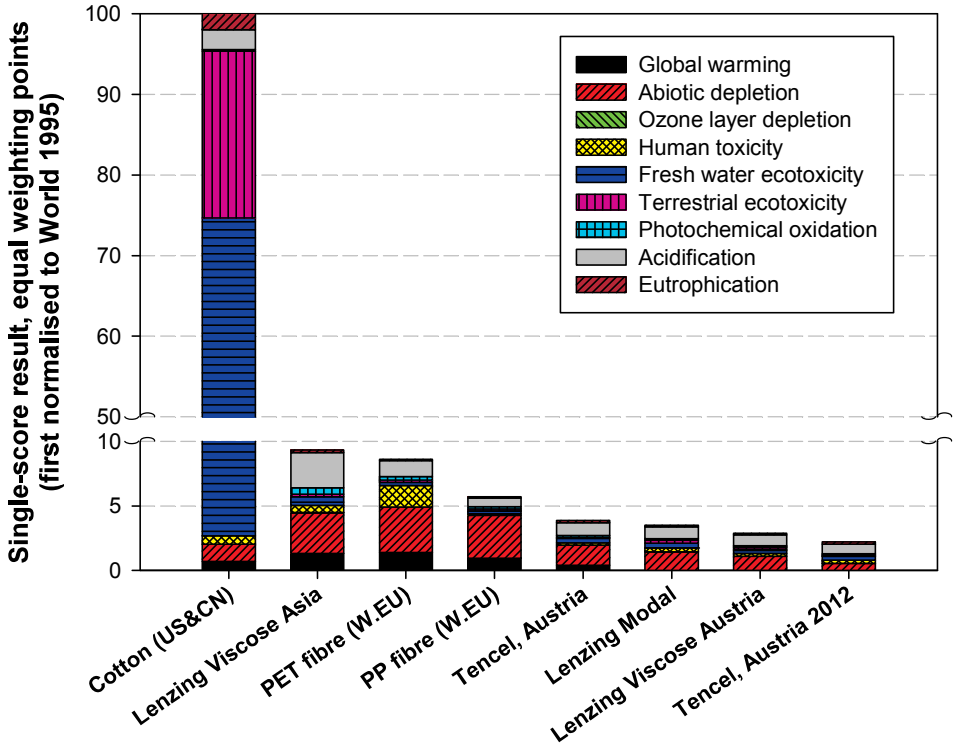

Figure 2. Single Score II, cradle-to-factory gate, first normalised to World 1995, equal weighting (cotton =100).

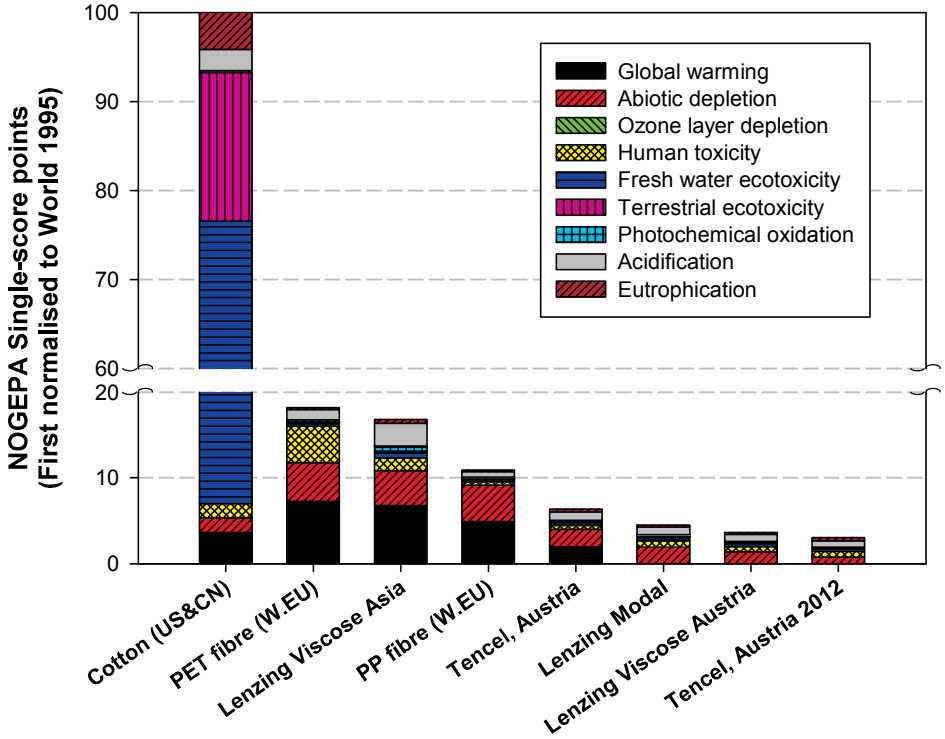

Figure 3. Single Score III, cradle-to-factory gate LCA result, first normalised to World 1995, NOGEPA weighting factors (Cotton =100).

Summary and conclusions

This report presents the single score analysis based on the LCA study of man-made cellulose fibres [3]. Single scores are calculated in order to arrive at an overall conclusion about the environmental attractiveness of the studied options. Five products of man-made cellulose fibres are compared with cotton (US & CN), PET (Western Europe) and PP (Western Europe).

For all three single scores, the four man-made cellulose fibres, namely Tencel Austria, Lenzing Modal, Lenzing Viscose Austria and Tencel Austria 2012, have lower impacts than all other studied fibres. Tencel Austria 2012 has the lowest impacts resulting from all three single score methods.

However, the three single score methods lead to different decisions for the fibre which has the highest impact. Based on Single Score I, Lenzing Viscose Asia has the highest score; although it scores very similar to cotton. Based on both Single score II and III, cotton has the highest impact; its single scores are substantially higher than those of all other fibres due to the high impacts of fresh water aquatic ecotoxicity and terrestrial ecotoxicity. Both Single Score II and III lead to the finding that Lenzing Viscose Asia and PET are comparable and both have lower overall impacts than cotton.

In conclusion, modern man-made cellulose fibres offer clear potentials for reducing the environmental impacts compared to cotton and petrochemical synthetic fibres (functional unit: one tonne of staple fibres).

References

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[6] Huppes, G., Warringa, G., Davidson, M.D., Kuyper, J., Udo de Haes, H.A. (2003) Eco-efficient environmental policy in oil and gas production in the Netherlands. , Netherlands Oil and Gas Producers Association (NOGEPA), The Hague.

Critical Review Statement

The study "LCA Single score analysis of man-made cellulose fibres" has been peer-reviewed by the following LCA experts:

- Professor Adisa Azapagic, The University of Manchester, UK;
- Jürgen Giegrich, Institute for Energy and Environmental Research (IFEU), Heidelberg, Germany; and
- Professor David Shonnard, Michigan Technological University, Houghton, MI, USA.

The critical review was commissioned by Lenzing AG, who also commissioned the LCA study. All reviewers are independent of the authors of the LCA study and Lenzing AG.
The critical-review process involved the following steps and activities:

- a review of the draft study report and the results, followed by a draft critical-review reports by each reviewer, in which a number of specific recommendations for improvements to the study were made;
- a review of the subsequent final study report, in which the authors of the study addressed all the points as suggested in the draft critical review; and
- the final critical review report (this review statement).

The aim of the review was to ensure that:

- the methods used to carry out the LCA are scientifically and technically valid given the goal of the study;
- the data used are appropriate and reasonable in relation to the goal of the study,
- the interpretations reflect the limitations identified and the goal of the study, and
- the study report is transparent and consistent.

Compliance of this study with the ISO 14040:2006 and 14044:2006 standards was not aimed for because these standards do not support single score analyses. The reviewers agree with the authors that the single score analysis presented in this report provides valuable additional insight so that these results are provided in addition to the main report titled "Life cycle assessment of man-made cellulose fibres".

Although the data were available for inspection, the critical review did not involve a review of the data used in the study so that all the findings of the review presented here are based solely on the draft and final reports and the discussions with the authors of the study and Lenzing AG.

NB: This critical review statement refers only to the report titled "LCA Single score analysis of man-made cellulose fibres" and does not cover the accompanying study "Life Cycle assessment of man-made cellulose fibres".

Adisa Azapagic Jürgen Giegrich David Shonnard

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