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Quantifying uncertainty elements in LCI modelling of chemical mixtures used for footwear production

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1. Introduction

The demand and consequent supply of clothing products has doubled in the last 15 years [1] and considered the large amounts of resources and materials that are needed in their production, it is becoming increasingly imperative to transition towards a more sustainable and circular textile industry. Among the materials needed to produce textiles, chemical substances represent a significant part as well as one of the major causes of concern. For this reason, many clothing brands have decided to reduce use of chemicals or transition towards greener alternatives. Life Cycle Assessment (LCA) is widely used in the textile industry to support this transition, but the assessment of chemical substances used within the industry remains a challenge in many ways. In fact, in the LCA of textile products, chemical substances are in general improperly inventoried and assessed [2]. The supply chain of textile products can be very long and complex, and data and information on the production and use of chemicals can be affected by many uncertainties, which are in practice a challenge in the compilation of an accurate Life Cycle Inventory (LCI). In this work we aim to quantify the total uncertainty associated with modelling, use and production of the chemicals needed in the production of footwear textiles as well as to decompose this uncertainty in its different qualitative and quantitative elements.

2. Materials and methods

In this study we consider the case of the production of a set of running shoes. We model the cradle to gate life cycle inventory of this product with primary data from the producer as well as using Ecoinvent 3.7.1 consequential as background database. We consider different sources of uncertainty depending on the data system (Table 1). For the foreground system we consider the uncertainty on the composition of the chemical mixture used in the production process provided by the producer's Material Safety Data Sheet (MSDS), and the uncertainty on the total amount of chemical mixtures used. For the background system we consider the uncertainty associated with the Ecoinvent-calculated impacts and the modelling uncertainty due to the practitioner's choice of dataset from the database.

Data system	**Uncertainty element**	**Data uncertainty example**
Foreground	Concentration ranges from MSDS	Chemical mixture formed as: Solvent= 60-80%, Solute= 20-40%
	Amount of chemical mixture	kg of mixture per functional unit: Mean=10.5 kg, St.dev=0.02
Background	Choice of background dataset	Different datasets for solvent production that are equally fit
	Ecoinvent-calculated impacts	GWP 1kg of solvent: Mean=X $kgCO_2eq$, St.dev=Y $kgCO_2eq$

Table 1: Identified sources of uncertainty in LCI modelling for this case study.

The overall uncertainty of the model is quantified stochastically by producing a large set of possible inventory values and structures, obtained by sampling randomly within the range of the uncertainties of each element. With the use of the LCA software Brightway [3], an impact assessment for global warming potential (GWP) is performed for each of the sampled values. The results of the simulation are then used to evaluate the contribution of each element to the total variance of the model output.

3. Results and discussion

Preliminary results (Figure 1) show that, when considering a given chemical mixture used in the production process, the spread in the results that is due to the uncertainty regarding the composition of the mixture is substantial (up to 15% in terms of relative standard deviation) and not negligible. Even larger is the uncertainty of results due to the choice of background dataset, that can lead to results different by a factor 0.2-0.3 (up to 100% difference) and which, being it subjective to the LCA practitioner, cannot always be clearly defined.

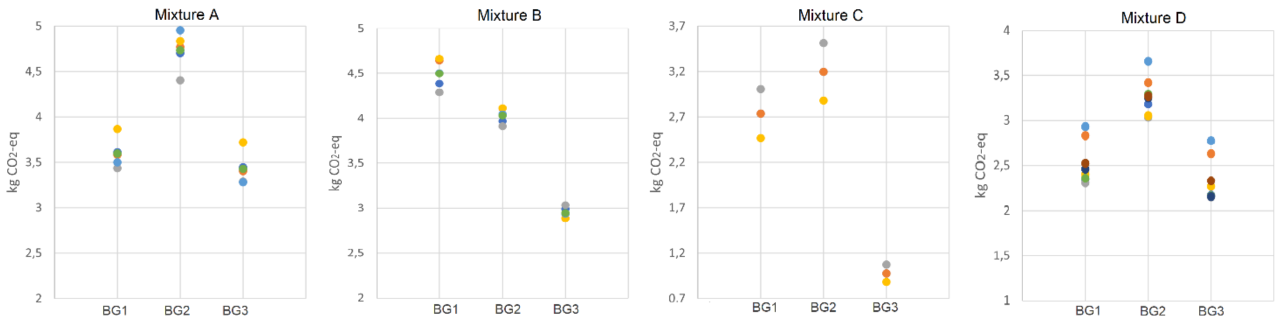

Figure 1: Example of GWP impact assessment results obtained assuming different equally likely models of mixture composition (colors) modelled with three different sets of background processes (BG) [4].

The results above are preliminary and are generated only considering the uncertainty due to the mixture composition and to the choice of background dataset. Other impact categories for both ecosystem and human toxicity show similar results. It has to be further considered that the full LCI of footwear production contains dozens of chemical mixtures and modelling each of these is associated with uncertainty (Table 1). The combination of the uncertainty associated with the multiple elements of table 1 into a full cradle-to-gate LCA is thus expected to produce an even higher uncertainty in the model output. In other words, we expect to see that a wide range of potential results can be obtained from performing the LCA of the same product, due to the multiple modelling and data uncertainties involved, all related to the production and use of chemicals and all belonging to the inventory stage (the LCIA stage is excluded from the scope of this analysis).

4. Conclusions

The expected outcome of the research is to determine the total uncertainty associated with LCA results due to different foreground and background sources of input uncertainty, and therefore the level of confidence in the LCI of industrial textile products requiring the application of chemical substances such as the one in this case study. A quantification of the uncertainties associated with the inventory stage is crucial to understand the accuracy of the LCA model results and to understand if comparative assertions are meaningful. The research demonstrates how increasing the accuracy and reliability of LCA can only be achieved via the explicit treatment of uncertainty, in the case of chemical mixtures and beyond.

5. References

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