

## **CORE ELEMENTS FOR THE REGIONALISED ASSESSMENT OF ABIOTIC RESOURCE USE - THEORY AND FEASIBILITY FROM A LIFE CYCLE PERSPECTIVE**

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### **ABSTRACT**

Growing demand for reliable information on sustainable abiotic resource use is promoting efforts to develop robust impact assessment methods for LCA purposes. This study assessed current methods to evaluate the reliability of their safeguard objectives and requirements for inventories for impact approaches of water and metals. Water use approaches consistently included freshwater scarcity, whereas the depletion potential of metals focused on varying aspects of their availability. Current inventories of freshwater use allow an appropriate assessment, although information on water released is still lacking. In contrast, due to inconsistent safeguard subjects, crucial aspects of metal inventories cannot be analysed sufficiently. Meaningful safeguard subjects and regionalised inventories are prerequisites for reliable assessment of abiotic depletion as a profound basis for decision makers.

### **INTRODUCTION**

According to Europe's thematic strategy on the sustainable use of natural resources, "European economies depend on natural resources, including raw materials such as minerals, (...); environmental media such as air, water and soil" (EC 2005). Growing awareness of the impacts of intensive resource use has led to discussions about the efficient use and management of natural resources. Therefore, efforts to develop comprehensive impact assessment methods for abiotic resource use are increasing in the life cycle community. The aim is to provide reliable information for decision makers in politics and industry and meet the demands of the debate regarding sustainable production and consumption.

Life cycle assessment (LCA) is widely used as a reliable tool to provide decision support in sustainable resource consumption such as water use. LCA practitioners rely on comprehensive inventory data sets and applicable methods in order to target relevant safeguard objectives. Water footprint methods focusing on spatial factors and use patterns at the specific location have recently been reviewed in terms of their applicability and methodological challenges (e.g. Kounina et al. 2013). The safeguard objectives and the required level of differentiation at

the inventory level for these methods differ significantly. Furthermore, other finite abiotic resources such as metals are being assessed with a number of approaches, yet there is no common consensus on the comparability of results.

In the present study, we analysed and compared selected resource use assessment methods regarding the reliability of their safeguard objectives and the level of regionalisation required for corresponding inventory data for the resources (A) water and (B) metals such as copper and lead. Furthermore, we examined the linkage between inventory data and safeguard subject, thus identifying core elements that allow a comprehensive and uniform assessment of abiotic resource use.

## **MATERIALS AND METHODS**

### *Eco-profile of Ingeo® polylactide (PLA)*

The current Ingeo® polylactide (PLA) production published by Vink et al. (2010) was chosen to evaluate the safeguard objectives of current water use assessment methods. In addition, we analysed the compliance of the PLA eco-profile according to the required level of regionalisation (A). The eco-profile comprises an agricultural part (corn production) and industrial processes from “cradle-to-factory gate”, hence covering all relevant stages of water use during the entire production cycle. Furthermore, we examined three assessment approaches of mineral resource depletion (B) to extract core elements that are crucial for a comprehensive assessment of abiotic natural resources.

#### *A) Comparison of water use assessment methods*

The water use assessment method of Ridoutt & Pfister (2013) aims to prevent regional water scarcity. Consumptive water use (CWU) and degradative water use (DWU) are captured in a single-score, stand-alone water footprint. Calculation of the CWU requires the Water Stress Index (WSI) at the specific geographic location and the quantity of water consumed. The DWU assessment requires information regarding emissions into water covered by the ReCiPe (2008) assessment framework, such as toxic chemicals and P- and N-compounds. The approach of Mila i Canals et al. (2009) targets the prevention of regional water scarcity as well, while also considering Ecosystem Water Requirements (EWR). Their method requires the same information as for the calculation of the CWU. In addition, it can assign different impact pathways to each water source, if the type of water source is included in the inventories. The water flow inventory of Boulay et al. (2011) seeks to prevent water scarcity caused by pollution. To allocate the water use to the specific categories developed in this approach, the quantity and quality of water extracted and released as well as water quality requirements of downstream water users are required.

#### *B) Comparison of metal use assessment methods*

The assessment methods van Oers et al. (2002), Schneider et al. (2011), and ReCiPe (2008) were applied to extraction of 1 kg copper and 1 kg lead to examine the different safeguard objectives and levels of regionalisation. Van Oers et al.’s (2002) model of “abiotic depletion potential” (ADP) assesses the global geological scarcity of abiotic resources. The model uses annual extraction rates and finite reserve data taken from the United States Geological Survey (USGS). The inventory requirement is the amount of metal used. Schneider et al. (2011) extend this concept by considering the anthropogenic stock to address the economic

availability of metals. Their model thus provides an “anthropogenic stock extended abiotic depletion potential” (AADP). The inventory requirement is the amount of metal used. In contrast, ReCiPe (2008) assesses the growing effort required for future extraction on account of ongoing resource extraction activities and based on data from the USGS deposits database. This more regionalised approach accounts for the spatially specific extraction conditions of a given resource. The inventory requirement is the amount of metal used.

## RESULTS AND DISCUSSION

### *A) Water*

With the information provided in the eco-profile of biobased PLA produced in the factory in Blair, Nebraska, USA, the WSI was determined to vary between 0.0385 and 0.9996, depending on the level of intensity of corn cultivation. One possible caveat of our analysis is the assumption that the individual WSI values would need to be weighted by the amount of corn cultivated prior to the calculation, since the eco-profile provided coarse-scale information only. However, it is not clearly stated whether the given values mean the actual amount of water consumed according to the definition, or if it was simply the amount of water extracted. Regarding the type of water source used, a differentiation is made between river, sea and groundwater in the eco-profile. However, the main part of the water is taken from public supply, and therefore the respective combinations of water sources needs to be taken from public databases. This requirement concerns neither LCI nor LCA practitioners but public institutions. According to the type of land conversion, no information on the land use prior to corn cultivation provided. The emissions to determine the DWU are listed in the eco-profile in sufficient detail. However, since the amount of water released is not included, a categoriation into quality classes according to Boulay et al. (2011) is not possible.

The three methods to assess water use that we analysed all focussed on regional water scarcity. Ridoutt & Pfister (2013) assess freshwater use and pollution related to the amount of water consumed by the depletion. Yet, the authors recommend further research pertaining the DWU calculation. Mila i Canals et al. (2009) also target freshwater consumption as well as the water demand of the surrounding ecosystem, but recognise the same lack of research concerning the EWR calculation. Boulay et al. (2011) evaluate the freshwater use and freshwater pollution as well as the water requirements of downstream users.

### *B) Metals*

For metal use, all inventory data were accessible, and no requirements were given here.

Van Oers et al. (2002) assessed the geological availability of metals and discussed the use of different reserve range data related with the selected safeguard objective. They emphasised the need for further research to define the problem of abiotic resource depletion in LCA. Schneider et al. (2011) addressed the economic availability of metals and thus contribute to the discussion of abiotic resource depletion. ReCiPe (2008) took a different path to assess the depletion of metals by focusing on the intergenerational sustainability of future costs of metals extraction. The three methods differed substantially in their definition of the safeguard subject, and hence, yield different results.

## CONCLUSIONS

Depending on the type of abiotic resource that is addressed, the safeguard subject varies between the assessment methods available. The evaluated methods regarding water use show a consistent development towards the impact assessment of freshwater scarcity as a safeguard subject and therefore enable the calculation of a reliable, concurrent result on a regionalised level. Current inventories provided by the industry already include the majority of data required by the assessment developers and are provided at an appropriate level of regionalisation. Thus, a reliable scarcity impact assessment of fresh water use is already available. For the evaluation of water consumed by pollution, the total amount of water released would further improve the reliability of the impact assessment. The analysed metal use assessment methods focused on varying safeguard objectives, as each of them focused on different aspects of resource availability. As they all aim to measure the “depletion potential” of mineral resources, it is important for decision makers in politics and industry to have reliable and meaningful results from LCA studies, which do not differ significantly when different assessment methods are applied. Regarding inventories, issues of regionalisation cannot be investigated as long as the methodological framework is not clearly defined. In conclusion, the assessment of abiotic resource use requires the definition of a meaningful safeguard objective and corresponding regionalised inventories. These pre-requisite core elements allow an evaluation of the impact of resource depletion and provide reliable decision support in terms of sustainable production and consumption.

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