Problems from including technospheric parameters in characterization factors for natural resources

Rickard Arvidsson[1], and Björn A. Sandén[1]

[1]Environmental Systems Analysis, Chalmers University of Technology, Vera Sandbergs Allé 8, 41296 Gothenburg, Sweden

E-mail contact: rickard.arvidsson@chalmers.se

1. Introduction

The world can be divided into two major compartments: the technosphere and nature. This distinction is generally adopted in life cycle assessment (LCA) practice. The life cycle inventory (LCI) analysis generally considers a product system in the technosphere, whereas the life cycle impact assessment (LCIA) is generally concerned with impacts in nature. Characterization factors (CFs) are therefore generally based on nature-given "intrinsic" properties of elementary flows, particularly for emission-related impact categories. For example, global warming potentials are calculated using the heat absorption and degradation rate of greenhouse gases. However, in LCIA methods for natural resources, we have noticed a tendency to include technospheric parameters. This practise, which deviates from the predominant use of parameters related to environmental processes in CFs for emissions, has not received much attention in the LCA community. Here, we discuss a number of problems arising from such inclusions.

2. Materials and methods

Existing LCIA methods for natural resources and their CFs were retrieved from ref. [1] and analysed regarding their use of technospheric parameters. A number of technospheric parameters were identified, including: (i) extraction rates, (ii) recycled contents, and (iii) prices. Potential problems from the inclusion of these three types of technospheric parameters in characterization factors are discussed below.

3. Results and discussion

3.1. Extraction rates

Extraction rates are included in abiotic depletion potentials (ADPs) (average annual or cumulative extraction) [2] and surplus ore potentials (SOPs) (cumulative extraction) [3]. The inclusion of extraction rates in CFs probably follows the rationale that the higher the annual or cumulative extraction of a resource, the worse it is with additional extraction of that resource. However, extraction rates vary over time. For example, cobalt extraction has roughly tripled between 2000 and 2020, and continues to increase. Frequent updating is therefore required to cope with such changes. Furthermore, the inclusion of extraction rates in the CF creates an interdependency between the LCI analysis and the LCIA, since extraction rates are also part of the inventory modelling. For example, assume a study comparing resource impacts of indium tin oxide vs graphene in transparent conductive layers, using an indium CF based on its current extraction E_0. But if graphene was to replace indium tin oxide in this application, which accounts for >50% of current indium use, indium extraction would likely be reduced to a lower value E_1, which would imply a new and lower CF. A hypothetical situation may be that graphene is superior to indium tin oxide given E_0, but not given E_1. The information received from LCAs using such CFs could therefore be counterproductive, in particular if the information is used to make decisions with irreversible or long-term consequences.

3.2. Recycled contents

Conventionally, recycling is modelled in the LCI analysis. There exist several approaches for this, such as the cut off approach and market price-based substitution. However, the supply risk methods ESSENZ [4] and ESP [5] also include global recycled contents for metals in their CFs. The rationale for including recycled contents in CFs is probably that the extraction of a resource is considered more severe if the resource is not recycled. However, many LCA studies also include recycled contents in the LCI analysis. When inventory data with recycled content are matched with CFs also taking recycled content into account, the benefit of recycling is double counted. The recycled content then reduces impacts both in the LCI analysis and in the LCIA. Furthermore, it introduces a risk of inconsistency: the global recycled contents in the CFs may not match the more specific recycled contents in the LCI analysis. For example, the global recycled content of chromium has been reported at 10-25%, while in Sweden about 60% of used chromium is recycled. In addition, since recycled contents not only vary spatially, but also over time, CFs based on recycled contents become time sensitive, although this may, again, be amended by frequent updating.

3.3. Prices

Prices are commonly used in economic allocation in the LCI analysis. In addition, prices have been applied in SOPs [3] and in the Cumulative Exergy Demand (CExD) indicator [6] to allocate impacts between different elements extracted in the same mineral or ore. Prices are also used for SOPs to extrapolate CFs for some elements for which CFs have not been calculated using the default procedure. There is a risk of inconsistency in studies applying economic allocation, if the prices used to calculate the CFs are not the same as those used in the economic allocation. In addition, prices are very time sensitive, potentially fluctuating considerably even on a daily basis. For example, even the average annual price of lithium carbonate has varied between ca 5000 USD/ton and ca 17 000 USD/ton in the period of 2010-2020, which is more than a factor of three. The need for updating would therefore be high for CFs that rely on prices.

4. Conclusions

It is possible to understand the rationales behind including the three discussed technospheric parameters in CFs for natural resources. However, as summarized in Table 1, these inclusions lead to a number of problems. Table 1 also proposes solutions to some of the problems. However, these solutions all come at a cost. For example, frequent updating of CFs is work intensive, and economic allocation may be otherwise recommendable in some studies. For the LCI-LCIA interdependency, we see no obvious solution, except for maybe restricting the use of CFs based on extraction rates to LCAs informing only short-term reversible decisions. Considering the identified problems, we recommend further critical discussions on the inclusion of technospheric parameters in CFs for natural resources.

Technospheric parameters	Problems identified	Possible solutions
Extraction rates	Time sensitivity LCI-LCIA interdependency	Frequent updating -
Recycled contents	Double counting Inconsistency Time sensitivity	No recycling benefits in LCI analysis Use same recycled content Frequent updating
Prices	Inconsistency Time sensitivity	Use same prices / no economic allocation Frequent updating

Table 1: Problems identified from including technospheric parameters in CFs for natural resources, and possible solutions.

5. References

[1] Sonderegger T, Berger M, Alvarenga R, Bach V, Cimprich A, Dewulf J, Frischknecht R, Guinée JB, Helbig C, Huppertz T, Jolliet O, Motoshita M, Northey S, Rugani B, Schrijvers D, Schulze R, Sonnemann G, Valero A, Weidema BP, Young SB. 2020. Mineral resources in life cycle impact assessment – part I: a critical review of existing methods. Int J Life Cycle Assess 25: 784-797.

[2] van Oers L, Guinée JB, Heijungs R. 2020. Abiotic resource depletion potentials (ADPs) for elements revisited – updating ultimate reserve estimates and introducing time series for production data. Int J Life Cycle Assess 25: 294-308.

[3] Vieira MDM, Ponsioen TC, Goedkoop MJ, Huijbregts MAJ. 2017. Surplus ore potential as a scarcity indicator for resource extraction. J Ind Ecol 21: 381-390.

[4] Bach V, Berger M, Henßler M, Kirchner M, Leiser S, Mohr L, Rother E, Ruhland K, Schneider L, Tikana L, Volkhausen W, Walachowicz F, Finkbeiner M. Integrated method to assess resource efficiency – ESSENZ. J Cleaner Prod 137: 118-130.

[5] Schneider L, Berger M, Schüler-Hainsch E, Knöfel S, Ruhland K, Mosig J, Bach V, Finkbeiner M. The economic resource scarcity potential (ESP) for evaluating resource use based on life cycle assessment. Int J Life Cycle Assess 19: 601-610.

[6] Bösch ME, Hellweg S, Huijbregts MAJ, Frischknecht R. 2006. Applying cumulative exergy demand (CExD) indicators to the ecoinvent database. Int J Life Cycle Assess 12: 181.