How uncertainties are handled in LCA – focus on the wastewater and textile sectors

S Heimersson*, H Holmquist*, M Svanström*, S Molander*, G Peters*

* Division of Environmental Systems Analysis, Department of Technology Management and Economics, Chalmers University of Technology, SE-412 96 Göteborg, Sweden. sara.heimerson@chalmers.se, hanna.holmquist@chalmers.se, magdalena.svanstrom@chalmers.se, sverker.molander@chalmers.se, petersg@chalmers.se

Abstract: Life cycle assessment (LCA) relies on large data samples and includes numerous choices and assumptions. This study aimed at reviewing to what extent relevant uncertainties are communicated and considered when interpreting LCA results, looking at current practices in LCAs on wastewater and textile systems. Our review showed that uncertainties are seldom communicated or considered in relation to the conclusions of the study, despite the availability of methods for propagating uncertainties in LCAs. We discuss that uncertainties and variation should at least be qualitatively assessed, and ideally be propagated from the life cycle inventory through the impact assessment.

Keywords: Life cycle assessment; sewage; sensitivity analysis

Introduction

Life cycle assessment (LCA) is an increasingly common tool for assessing impacts from an environmental systems perspective, having been used in the wastewater and textile sectors since the 1990s. LCA is a quantitative tool that is dependent upon many choices and assumptions, and relies on large data collection efforts, by the LCA practitioner for the specific study, or included in pre-calculated characterisation factors. This implies that, as is the case for many other kinds of strategic assessment tools such as financial cost-benefit analysis, many types of uncertainties (e.g. model uncertainty, or uncertainty related to data gaps or errors) are embedded in the results, in addition to the natural variability in certain data. Figure 1 illustrates uncertainties in LCAs grouped into two categories, related either to the problem of getting the right numbers, or getting these numbers right.

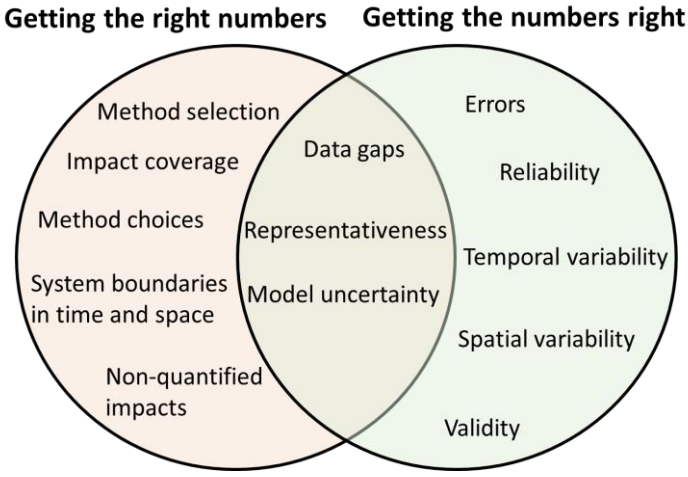

Figure 1 Uncertainty in LCAs grouped into two categories, those relating to "getting the right numbers" and those relating to "getting the numbers right". In this study the focus is on the latter. 'Method selection' refers to the choice of LCA, 'method choices' refer e.g. to choice of LCA-type (e.g. attributional) or LCIA method for a certain impact category, 'non-quantified impacts' refer to impacts for which LCIA methods are not yet available.

ISO14044 (ISO, 2006) points out the importance of interpreting LCA results in light of their uncertainties, and e.g. Groen & Heijungs (2017) highlights the need for uncertainty assessments to avoid drawing incorrect conclusions. Guidance and methods for propagating uncertainties have been published in a large number of LCA method papers (see e.g., Huijbregts (1998a-b), Ciroth et al. (2004), Groen et al. (2014), Groen et al. (2017) and Mendoza Beltran et al. (2018)). It has thus been shown that considering uncertainties in LCA results is important, and methodology to quantify uncertainties exists. However, to what extent is this applied in practice?

The current study aims to identify which types of uncertainties that to date are covered in LCAs, and how these are assessed. For this purpose, a review of the practice for handling uncertainties in recently published LCAs in two very different industrial sectors, wastewater and textile, was performed. We focused on the uncertainties regarding "getting the numbers right" in Figure 1. This implies that the uncertainties of the choices, assumptions and data in the quantification of impacts are in focus, rather than whether the methods chosen for the assessment are suitable.

Material and Methods

The selection of relevant papers was made from peer-reviewed journals indexed in the Scopus database. The searches were limited to papers published after 2012. The search for studies reporting on LCAs in the wastewater sector was made in July 2018, and for the textile sector in December the same year.

To identify the total number of LCAs for each sector, a search was made for papers having life cycle assessment/LCA in the title or among author-defined keywords, together with sector-specific terms such as textile/fabric or 'wastewater treatment'/biosolids/'sewage sludge' etcetera. To identify the LCAs with extra focus on uncertainty amongst those papers, the ones containing uncert* OR sensitivit* OR "error management" OR varia* in title, abstract or keywords were selected from the initial search results.

The handling of uncertainties in the resulting papers were mapped for a number of categories, as shown in in Table 1, which is a modified version of a framework suggested by Huijbregts (1998a).

Results

Of the 158 studies published on LCAs in the wastewater sector, 23% mentioned uncertainties, or the other search terms listed above, in the title, abstract or keywords. Corresponding figures for the textile sector were 57 studies in total, of which 26% mentioned uncertainties. These results indicate that the majority of the published studies in both sectors do not focus on uncertainties to the extent that it is mentioned in the abstract.

The categories of methods used to assess uncertainty are displayed in Table 1. As can be seen uncertainty assessment was applied to a very limited extent, and mainly through scenario modelling or a data quality assessment or by following method standards.

Table 1 Share of reviewed LCA papers (% of reviewed wastewater sector papers / % of textile sector papers) covering different types of uncertainty. The table is structured based on a framework by Huijbregts (1998a), which has been slightly adjusted to fit the current study. n.s = no studies found in this category. Empty cells indicate that no results were expected. Grey cells implies that the category is further divided into subcategories on the rows underneath.

	Uncertainty due to choices		**Model uncertainty**		**Parameter uncertainty**	
	LCI	**LCIA**	**LCI**	**LCIA**	**LCI**	**LCIA**
Data quality assessment	n.s	n.s	n.s	n.s	10% / 53%	n.s
Probalistic simulation						
- Extensive Monte Carlo			n.s	n.s	10% / 0%	n.s
- Limited Monte Carlo			n.s	n.s	7% / 13%	n.s
- Other method			n.s	n.s	0% / 7%	n.s
Correlation and regression analysis			n.s	n.s	3% / 13%	n.s
Additional measurements						
- Field measurements			n.s	n.s	n.s	n.s
- Extended desktop data collection			n.s	n.s	3% / 0%	0% / 7%
Scenario modelling	13% / 7%	20% / 0%	n.s	n.s	50% / 53%	n.s
Standardisation	43% / 40%	20% / 27%	n.s	n.s	n.s	n.s
Expert judgements	n.s	n.s	n.s	n.s	n.s	n.s
Non-linear modelling			n.s	n.s	3% / 0%	n.s
Multi-media modelling			n.s	n.s		

Discussion and conclusions

Due to their complexity and the large amount of diverse data needed, LCAs will always be associated with uncertainties. As LCA results always should be interpreted in relation to the related uncertainty (ISO, 2006), it is problematic when LCAs, as those in the wastewater and textile sectors, do not place more focus on uncertainties. With methods available to propagate uncertainties it is surprising that few of those are used in the reviewed studies. A qualitative discussion of uncertainties should be a minimum requirement.

With a recent focus on quantitative assessment of uncertainties in LCA studies (see e.g. Mendoza Beltran et al. (2018)), ideally, future LCAs will to a greater extent than before propagate uncertainties/variation from the life cycle inventory through the life cycle impact assessment. Such a propagation can use qualitative approaches if quantification is not possible. This will make it possible to better ascertain that identified differences are true and not just a matter of chance. However, often the purpose of an LCA is to gaze into the future and imagine possible scenarios, in which case traditional statistical error analysis may be infeasible or irrelevant in comparison to the scale of the scenario uncertainties. In such cases the LCA analyst must of course place extra care in the selection of scenarios to ensure that such a future study become relevant (see e.g. Börjeson *et al*. (2006)).

The LCA articles selected for this review included uncertainty related terms in the title, abstract or keywords, assumingly placing larger focus on this topic than the other LCA studies covering the same sector. Additional sampling, with other criteria, from the LCA studies on the wastewater and textile sectors, would be welcome to verify the results presented here. Future studies also need to identify in which of the LCA studies quantitative uncertainty analysis would have been feasible and relevant despite it was not applied, and in those cases, what is, in practice, hindering the use of one of the methods suggested for handling uncertainty in LCAs in literature.

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