"Less is Better" and "Only Above Threshold": Two Incompatible Paradigms for Human Toxicity in Life Cycle Assessment?

José Potting, Michael Hauschild, Henrik Wenzel

Process and Production Engineering, Department of Manufacturing Engineering, Technical University of Denmark, Building 424, DK-2800 Lyngby, Denmark

Corresponding author: José Potting; e-mail: jp@ipt.dtu.dk

Abstract

The absence of spatial and temporal information in the data from a typical Life Cycle Inventory puts constraints on the possibilities of subsequent Life Cycle Impact Assessment to predict actual impact. Usual methods for Life Cycle Impact Assessment (often referred to as "less is better" methods) make only limited use of spatial and temporal information, because they predict concentration increases rather than full concentrations. As a consequence it does not seem possible to evaluate whether a threshold value is surpassed. The resulting poor accordance between the predicted impact and the expected occurrence of actual impact is a major problem. This problem is particularly relevant for human toxicity assessment, since the probability of surpassing thresholds here traditionally is the main point of attention. A considerable group of practitioners suggests to follow an "only above threshold" principle by introduction of assessment tools from risk assessment and environmental impact assessment in LCA. Intensive debate is going on about possibilities and limitations of "less is better" and "only above threshold". The debate is obscured by two underlying discussions (about no-effect-levels and about data-availability) that are partly, but not fully intertwined. Both principles tend to be given fixed positions in these discussions, and are therefore often put forward as fundamentally different and incompatible with each other. This article entwines the discussions, shows parallels between both principles, and uses these parallels to present a new method for Life Cycle Impact Assessment of human toxicity from air emissions that— with limited data requirement from Life Cycle Inventory — can take as well threshold evaluation and spatial source-differentiation into account.

Keywords: Human toxicity, methodology; methodology, paradigms, less is better, only above threshold; pollution prevention, emissions, methodology

1 Introduction

The international agreement about main lines of Life Cycle Assessment (LCA) is on a general level, since the method is not yet fully developed (CONSOI et al. 1993, ISO/TC-207/SC5). In particular the impact assessment phase has not crystallized out. A major problem is the poor accordance between the impact predicted by a typical Life Cycle Impact Assessment (LCIA) and the expected occurrence of actual impact, in particular for human toxicity. The absence of spatial and temporal information in the data from a typical Life Cycle Inventory (LCI) puts constraints on the possibilities of subsequent LCIA to predict actual impact. Usual LCIA methods calculate similar impact for all emissions of the same size and substance, independently of the circumstances under which the emissions take place. In particular, for human toxicity assessment this may result in obviously wrong conclusions as illustrated in Box 1.

There is ongoing discussion about the possibilities and limitations of the impact assessment phase in LCA to predict actual impact. Two main positions can be distinguished: methods following the "less is better" principle (first used and still typical), and methods following the "only above threshold" principle (later introduced). The two principles and related methods are often put forward as fundamentally different and incompatible with each other (BARNHOUSE et al., 1997; UDO DE HAES, 1996; WHITE et al., 1995). We only partly agree and see, quite the reverse, clear analogies. However, these analogies are obscured by two intertwined discussions in which both principles unnecessarily seem to take fixed and opposite positions: The discussions about threshold evaluation in LCIA, and the availability of data from LCI to support such evaluation.

In this article, we will demonstrate that the only fundamental difference between "less is better" and "only above threshold" methods is the way they deal with exposure situations below and above threshold values. Neither the availability of spatial and temporal data, nor the level of sophistication of analytical tools for impact assessment are fixed in relation to the method being "less is better" or "only above threshold". This is illustrated with the assessment of human toxicity from air emissions. Next, we combine analytical tools of both prin-
Box 1: Three examples where Life Cycle Impact Assessment of human toxicity obviously results in wrong conclusions if circumstances in which emissions take place are disregarded

First example: single source exposures below/above threshold

In the Life-Cycle of linoleum, emission of toluene takes place during manufacture as well as in the use stage from the adhesive for laying the linoleum. Considerable dilution of the outdoor emission from linoleum manufacture results in ambient concentrations that remain far below the no-adverse-effect-level for toluene. The indoor toluene emission from the adhesive, however, gives cause to concentrations and exposures above the no-adverse-effect-level during at least 10-15 days (Gustafsson, 1992; Potting and Blok, 1994).

Second example: multiple source exposures below/above threshold

Exhaust gases from transport vehicles contain a mixture of substances. Concentrations and exposures above no-effect-level are not expected to occur easily from roads outside built-up areas. The traffic density and moderate circulation on arterial roads in built-up areas easily brings about concentrations above no-effect-level by accumulation of exhaust gasses from all vehicles passing. In addition, also population density in the vicinity of these roads will be higher. According to Kilde et al. (1995), kilometres from lorry traffic in Denmark go for about 20-40% through built-up areas, 15-40% on motorways and 40% on secondary roads.

Third example: single source exposures below threshold

The emissions from electricity production for the public grid will be released from a stack that is often higher than 100 metres, whereas the stack height for an average production process is expected to be around 25 metres. Though both emissions will probably not give cause to concentrations above threshold, dilution from a high stack is considerably larger than that of a low stack. The actual exposure increase by the emission from electricity production is therefore expected to be much smaller than that from an average production process (though in the former case the surface of the area with an increased concentration, and therewith the number of exposed people may be larger).

practitioners have suggested to omit the impact assessment phase from LCA. This opinion is not shared by the mainstream of LCA practitioners, and it also contradicts with the requirements for an LCA as formulated by acknowledged authoritative bodies such as SETAC (Consoli et al., 1993; Fava et al., 1993) and ISO (ISO/TC207/SC5). However, both SETAC and ISO recognize explicitly that LCA, and in particular the impact assessment phase, is still in an early stage of development.

Usual LCIA methods do not require, or only make limited use of spatial and temporal information by following a "less is better" principle. In present "less is better" methods, all emissions of a given substance are summed up throughout the life cycle. In a subsequent step, the cumulated emission of this substance is aggregated by equivalency assessment with the cumulated emissions from other substances contributing to the same impact category. All emissions are considered to be relevant on the basis of their intrinsic harmful properties. The underlying assumption is that all emissions give rise to concentration or deposition increases at sites that all have a similar sensitivity to the given substance. It allows for comparative analysis of the differences in emissions between product alternatives (Udo de Haes, 1996; White et al., 1995).

The "less is better" methods may result in a poor accordance between the expected actual impact and the impact predicted by LCIA. Examples are given in Box 1. Most "less is better" methods are, among others, strongly debated for their inability to discriminate between processes with emissions causing concentrations below and above a threshold value (first and second example in Box 1). The most radical suggestions for an improved impact assessment is put forward by White et al. (1995), and follows the principle of "only above threshold".

2 "Less Is Better" and "Only Above Threshold"

The data from a typical LCI do not contain time and space specification. The absence of this information puts constraints on the possibilities of LCA to predict actual impact. Some