The Part of Life-Cycle-Assessment for Biodegradable Products: Bags and Loose Fills

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Abstract: Life cycle assessments are of increasing importance for industrial development and for decision making in politics and at customers. The International Standard ISO 14040 guarantees high quality of LCA studies specifying the principles and requirements. The LCA study of Mater-Bi bags – incl. critical external review – performed the advantage of the biodegradable product compared to PE- and paper-bags and is used as selling argument for potential customers. The LCA of the Mater-Bi loose fills compared to EPS loose fills investigated different production variants and serves for process improvement.

1. INTRODUCTION

Biodegradable materials (BDM) were developed and sold as an ecological alternative to conventional plastics. The use of BDM instead of normal plastics is supposed to be less ecologically harmful, e.g. to reduce the impacts on climate changes (CO_2) and to save non renewable resources.

The economy developed a wide range of instruments to measure the economic success or failure of enterprises. Similar tools are requested to quantify the ecological impacts associated with manufactured and consumed products. One of the techniques being developed for this purpose is Life Cycle Assessment (LCA) a mean of environmental management systems[1]. Since 1997 the International Standard ISO 14040[2] has described principles and set frameworks for conducting and reporting LCA studies.

In practice there is a big number of LCA-software-tools available using different models for the impact assessment[3,4]. Several high quality LCA-studies on BDM have been recently accomplished, so that some data and benchmarks of BDM are available now[5-13].

2. PURPOSE OF LCA

LCA studies the environmental aspects and potential impacts throughout a product's life (i.e. from the cradle-to-grave) from raw material acquisition through production, use and disposal (Fig 1). The general categories of environmental impacts needing consideration include the exploitation of resources, human health, and ecological effects.

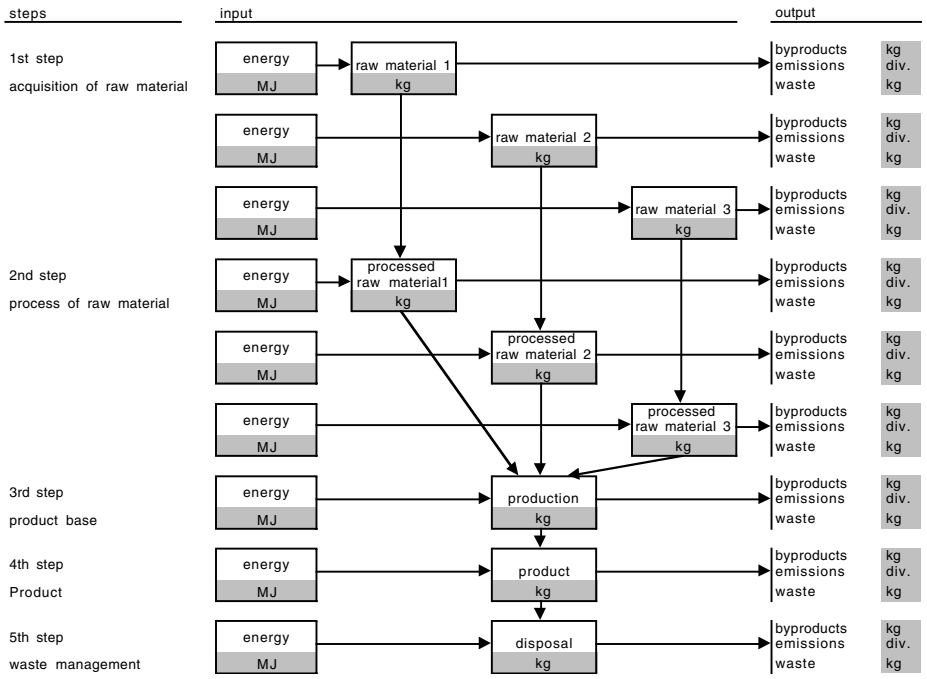

Figure 1. Scheme of a products life cycle

2.1 Internal use

LCA assists in identifying opportunities to improve the environmental aspects of products at various points of their life cycle. As it shows the environmental impacts separately for every production step in a processing plant, it is easy to find the most expensive step from the ecological (e.g. CO2-emissions) and – in a restricted sense – from the economical point of view (e.g. energy demand) as well. Improving the most relevant steps is most advantageous for the environmental management system of an enterprise and might bring in money too, especially in the long term.

Cargill Dow Polymers (CDP) regards LCA to be an excellent process development tool to provide an insight about the polylactic acid (PLA) production, to set process improvements goals and to provide eco-profile data to be used by practitioners in performing their own life cycle studies[9]. On the other hand, CDP wants to make information available for the shareholders and the public due to the increasing demand of transparency. CDP started the first LCA in 1993 and updated it 3 times. In 2003, when the 140000 metric ton plant (MTPA) facility will be operative, new engineering data will be available for a next update.

As the biodegradable Mater-Bi loose fills can be obtained by using a conventional extruder, Novamont SpA evaluated their LCA to find the most ecologically favourable way for their production. The production of loose fills from granules directly at the customer's site, turned out to be most convenient as it minimized the transportation costs[8].

2.2 External Use

LCA can be used for decision making in industry, governmental and non-governmental organisations, e.g. for strategic planning and priority setting, and for marketing as an environmental claim, eco-labelling scheme or environmental product declaration.

The German agency of environment insists on LCA studies of BDM including comparative assertions as a base for the political strategy for waste management (disposal of BDM in the organic waste or not) and packaging taxes.

The LCA study of the biodegradable Mater-Bi bags serves for decision making i.e. in waste management federations to choose the bags, which are allowed in the organic waste collection and as a selling argument

for potential customers. This study was the first LCA on bioplastics to be calculated and reported according to the International Standard ISO 14040 including an external critical review[7].

An increasing number of customer cares about the environmental engagement of the bidders and therefore a good documentation of the products' life cycle might be advantageous.

However, LCA studies proposed for external use – especially if results support comparative assertions – raise special concerns and require a critical review, since this application is likely to affect interested parties which were not involved in the calculating process.

3. LCA ACCORDING TO INTERNATIONAL STANDARD ISO 14040

LCA studies accomplished according to the International Standard ISO 14040 guarantee high quality, because the International Standard specifies the general framework, principles and requirements for conducting and reporting them. However, no description of the LCA technique is reported in detail. Further International Standards ISO 14041, ISO 14042 and ISO 14043 provide additional details regarding methods concerning the various phases of LCA.

The International Standard ISO 14040[2] dictates that LCA include 4 phases: definition of goal and scope, inventory analysis, impact assessment and interpretation of results (Fig 2).

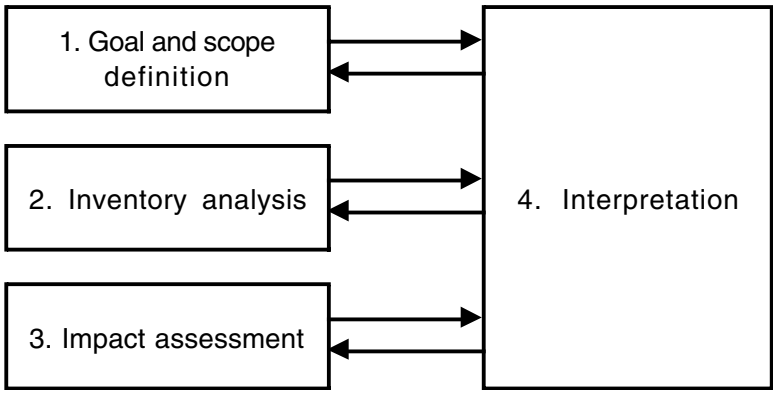

Figure 2. Phases of an LCA

3.1 Goal and Scope

The goal of the LCA study has to state unambiguously the intended application, the reasons for carrying out the study and the intended audience.

The most crucial points in defining the scope of an LCA study are the functional unit, the product system studied, the system boundaries, the types of impact and the methodology of impact assessment and subsequent interpretation to be used, the data requirements and the type of critical review, if any.

3.2 Inventory Analysis

Inventory analysis involves data collection and calculation procedures to quantify relevant inputs and outputs of a product system. The qualitative and quantitative data for inclusion in the inventory have to be collected for each unit process within the system boundaries. The data constitute the input to the life cycle assessment.

3.3 Impact Assessment

The impact assessment phase of LCA is aimed at evaluating the significance of potential environmental impacts by using the results of the life cycle inventory analysis. In general, this process involves association

of inventory data with specific environmental impacts and attempting to understand those impacts. The phase of the impact assessment mostly includes elements such as: classification (assigning of inventory data to impact categories), characterisation (modelling of the inventory data within impact categories) and possibly evaluation (aggregating the results). Evaluation is a very sensitive process and should only be used in special cases provided that the data prior to evaluation remain available.

The methodological and scientific framework for impact assessment is still being developed. Models for impact categories are in different stages of development. There is subjectivity in the life cycle impact assessment phase such as the choice, modelling and evaluation of impact categories. Therefore, transparency is critical to impact assessment to ensure that the assumptions are clearly described and reported.

3.4 Interpretation

Interpretation is the phase of LCA in which the findings from the inventory analysis and the impact assessment are combined to reach conclusions and make recommendations.

The findings of this interpretation may take the form of conclusions and recommendations to decision-makers, consisting of the goal and scope of the study.

3.5 Report

The results of the LCA have to be reported fairly, completely and accurately to the intended audience. Which means that the results, data, methods, assumptions and limitations have to be transparent and presented in sufficient detail to allow the reader to understand the complexities and trade-offs inherent in the LCA study.

When the results of the LCA are to be communicated to a third party, a third party report has to be prepared, covering a critical review among other things.

3.6 Critical Review

The use of LCA results to support comparative assertions raises special concerns and requires critical review since this application is likely to affect interested parties that are external to the LCA study. A critical review may facilitate understanding and enhance the credibility of LCA studies, for example, by involving interested parties.

The critical review process has to ensure that

- the methods used to carry out the LCA are consistent with the International Standard ISO 14040.
- the methods used to carry out the LCA are scientifically and technically valid.
- the data used are appropriate and reasonable in relation to the goal of the study.
- the interpretations reflect the limitations identified and the goal of the study.
- the study report is transparent and consistent.

Dependent on the size and the intended audience, different kinds of critical review are possible: internal or external expert review and review by interested parties.

4. KEY FEATURES OF LCA

LCA is always a snapshot that considers the actual state of the art. Therefore comparing results from LCA studies calculated 2 years before or later is “apple-to-pear-comparison”.

LCA is never an exact calculation because most of the parameters can not be measured exactly and are more or less assumptions. Data from literature (e.g. for energy or transports) are average values. Some LCA-software tools consider this inaccuracy and allow a special error of calculation.

The scope, assumptions, description of data quality, methodologies and output of LCA studies have to be transparent. LCA studies should discuss and document the data sources and be clearly an appropriately communicated. The depth of detail and time frame of an LCA study may vary to a large extent, depending on

the definition of goal and scope. Therefore results of different studies can hardly be compared to each other. The quality of the database determines the quality of the LCA.

5. BIODEGRADABLE BAGS FOR ORGANIC WASTE COLLECTION

Life cycle assessments were applied in 1997/98 to analyse the degree of ecological damage caused by the production and disposal of Mater-Bi bags used in households to collect organic waste. Paper bags "haushalt kompost", which can be composted, and PE multipurpose bags, which cannot be composted, were used as points of reference.

The life cycles included raw material acquisition, the production and processing and/or disposal of the bags as well as routes of transport. Packaging, distribution, utilisation and collection as well as transport to the wholesalers could not be considered due to the dependency of these processes on the respective bulk buyers and retailers.

Life cycle profiles were drawn up using the modified impact-oriented model [3,5] and the impact categories of Eco-Indicator '95[4]. All in all the degree of ecological damage could be identified in thirteen different impact categories. The calculations were obtained by application of the life cycle assessment software EMIS (Environmental Management and Information System, Version 2.2). Most data were taken either from internationally recognised literature (energy supply[14], production and processing of paper, PE [polyethylene][15,16], disposal processes[17,18], transport[19]) or they were supplied by the manufacturers. In order to analyse sensitivity, new unit processes for the agricultural production of maize in France and for organic waste incineration were created. Assessments were carried out separately for each impact category because of previously specified boundaries of reliability.

The production and disposal of Mater-Bi bags (Table 1) causes less environmental damage than that of paper bags "haushalt kompost" in eleven out of thirteen impact categories. In the two remaining categories the Mater-Bi bag causes the same or greater degree of ecological damage.

The Mater-Bi bag and the multipurpose PE bag are equivalent in seven impact categories; the Mater-Bi bag achieves better results in four categories, but worse results in the two remaining categories. However, Mater-Bi bags generate less environmental damage than PE multipurpose bags in ten categories if one considers the waste adhering to the bags and being incinerated together with them. In two categories both bags obtain the same results, while in one category the production of Mater-Bi bags generates more environmental damage. It does not prove relevant for the overall results whether maize produced in Switzerland or respectively in France, is used. Mater-Bi bags made of French maize were selected for the overall assessment as maize on the European market is mainly produced in France.

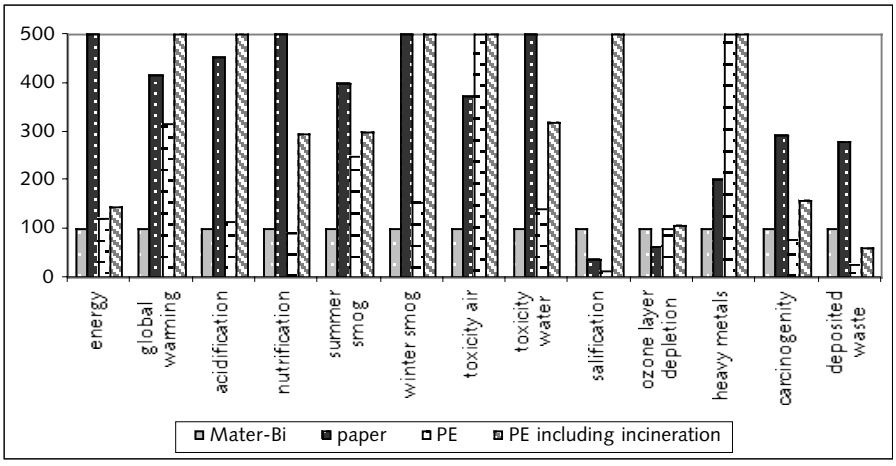

Chart 4. Assessment of the three products (Mater-Bi, paper and PE bag) ac. to the modified impact oriented model[3,5] and Eco-Indicator '95[4] standardised to the Mater-Bi bag.

Assessments of the Mater-Bi bag and the multipurpose PE bag show that both can be regarded as equivalent, as long as the focus remains on production and disposal (disregarding compostable waste incineration). If the compostable waste that is incinerated with the PE bags is taken into account, the Mater-Bi bag offers a better ecological value. The production and disposal of the paper bag is bound to cause considerably more damage to the environment than that of the Mater-Bi bag (Table 1).

Table 1: Mater-Bi bag in comparison with other products. Read: "In comparison with product A in 13 impact categories a Mater-Bi bag made of French maize is significantly better / better / comparable / worse / significantly worse."

Mater-Bi bag in comparison with	paper bag	PE bag	PE bag [a)]
much better	5	2	6
better	6	2	4
comparable	1	7	2
worse	1	0	1
much worse	0	2	0
total result	**better**	**comparable**	**better**

a) Including organic waste incineration

There is no doubt that for the municipal collection of organic waste biodegradable bags should be recommended. From an ecological point of view the Mater-Bi bag has to be given preference over the other compostable bag (paper bag "haushalt kompost"). Short routes of transport and minimal use of packaging material should be weighty criteria as for the choice of product.

The study was conducted and reviewed according to International Standard ISO 14040 (ISO 14040, paragraph 7.3.2 ["external expert review"] by Dr. Gérard Gaillard from the Eidgenössische Forschungsanstalt für Agrarwirtschaft und Landtechnik, "Federal Research Centre for Agriculture and Cultivation Methods").

6. BIODEGRADABLE LOOSE FILLS

Life cycle assessments were applied to analyse the degree of ecological damage caused by the production and disposal of loose fills made out of Mater-Bi pellets in comparison to those made of expanded polystyrene.

The life cycle analysis includes raw material acquisition, production, processing and disposal of the loose fills as well as transport. Packaging, distribution, use and collection are not considered due to the dependency of these processes on the respective bulk buyers and retailers.

Life cycle profiles were drawn up using the modified impact-oriented model[3,5] and the impact categories of Eco-Indicator '95[4]. All in all the degree of ecological damage could be identified in thirteen different impact categories. The calculations were obtained by application of the life cycle assessment software EMIS (Environmental Management and Information System, Version 2.2). Most data were taken either from internationally recognised literature (energy supply[14], production and processing of Expanded Poly(styrene) [EPS][15,16], disposal processes[17,18], transport[19]) or the manufacturers supplied them. In order to analyse sensitivity new unit processes for the wastewater treatment of Mater-Bi loose fills were created. Assessments were carried out separately for each impact category because of previously specified boundaries of reliability.

The production and disposal of Mater-Bi loose fills causes less environmental damage than the one of EPS loose fills in eight of thirteen impact categories, but more in two categories. The emissions in the three remaining categories are comparable (Table 2).

Assessments of the Mater-Bi loose fills under different production and disposal management show small changes in the eco-profiles in comparison to the basic calculation.

- Disposal of Mater-Bi loose fills in a wastewater treatment instead of composting plant
- Production of Mater-Bi loose fills from pellets directly at the customer’s site, avoiding transportation of the loose fills.
- Production of loose fills directly from starch, avoiding production and transportation of pellets

As Mater-Bi loose fills were not longer compared with an other product but with themselves considering different production variants, two new, closer limits were defined for the assumption of the production variants of Mater-Bi loose fills (Table 2).

Table 2: Mater-Bi loose fills in comparison with EPS loose fills and different production or disposal management. Read: " In comparison with product A in 13 impact categories Mater-Bi loose fills are significantly better, better, (slightly better), comparable, (slightly worse), worse, significantly worse."

Mater-Bi loose fills in comparison with	EPS loose fills	Mater-Bi loose fills in waste water treatment	Mater-Bi loose fills produced at the customer's site	Mater-Bi loose fills produced directly from starch
much better	3	0	0	0
better	5	2	0	0
slightly better	-	2	0	0
comparable	3	9	7	10
slightly worse	-	0	6	3
worse	2	0	0	0
much worse	0	0	0	0
total result	**better**	**slightly better**	**slightly worse**	**comparable**

The sensitivity analysis of the Mater-Bi loose fills under different production and disposal management doesn't show relevant changes to the basic calculation (see Fig 5 and Table 2).

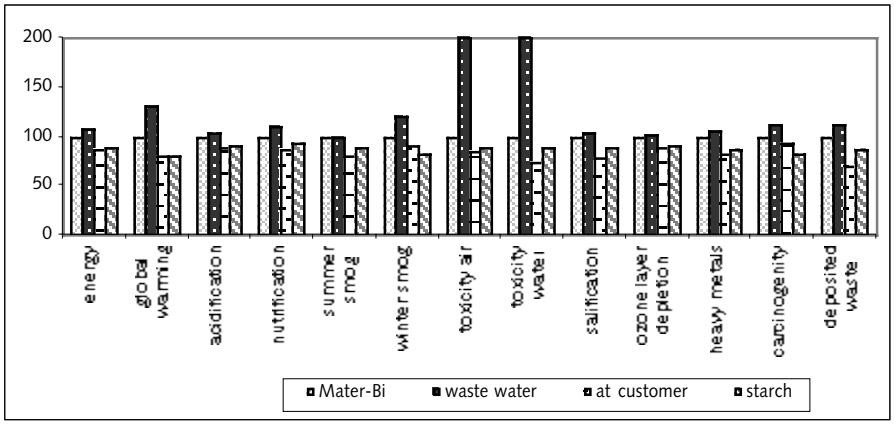

Figure 5. Assessment of the four variants of Mater-Bi loose fills (basic calculation, waste water treatment, production at the customer, production directly from starch) ac. to the modified impact oriented model[3,5] and Eco-Indicator '95[4] standardised to the Mater-Bi loose fills basic calculation.

In each two categories it is better or respectively slightly better than the waste water treatment of Mater-Bi loose fills. The production of Mater-Bi loose fills at the customer's site and directly from starch is slightly better than the normal production of Mater-Bi loose fills (basic calculation), in 6, respectively 3 categories.

From the ecological point of view the Mater-Bi loose fills have to be given preference over EPS loose fills. The disposal of Mater-Bi loose fills in wastewater treatment is possible but shouldn't be pushed due to the small ecological disadvantage. Producing Mater-Bi loose fills at the customer's site or directly from starch save economically and ecologically expensive transports.

7. CONCLUSION

- LCA studies are of increasing importance for biodegradable products: to improve the production process, for external communication, for politics.

- International Standards such as ISO 14040, available database and special software tools guarantee a high quality and decreasing costs of the calculations.

- The change of agriculture to a more sustainable farming would amplify the ecological advantage of biopolymers made out of renewable resources. This aspect becomes more and more relevant regarding the increasing excess of farmland.

- LCA is a necessity for products that are intended to be sold using ecological arguments.

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