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Comparative Life Cycle Impact Assessment in Global Warming Potential for Pharmaceutical Packaging purpose

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ABSTRACT
Pharmaceutical companies are increasingly imparting a lot of importance becoming more environmental friendly and sustainable by developing products that are having the same medicine value but reduced environmental impact. Materials that are used in packing applications have a lot of environmental impact that results with increased Global Warming Potential (GWP). The researchers, named in the abstract, are using SimaPro software and BUWAL database to make Life Cycle Impact Assessment (LCIA) for a product group (cosmetic mineral water) in pharmaceutical company, in order to determine the environment state by determining Environmental loads (EL). Having the results of the study impact characterization framework is developed and better evaluation for existing and new company's products is encouraged.

Keywords: *LCIA, Pharmaceutical packing, GWP, EL*

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I. INTRODUCTION

Every year more and more companies are becoming concerned with the environmental impacts of their activities. These companies span the entire spectrum of industries, from energy producers to product manufactures and service-oriented companies. They want to be able to understand the environmental impact they cause, in order to control or, better yet, to avoid them. Corporate managers see the systematic reduction of environmental impacts as one way to help them accomplish the goal. There is also a general growing desire by companies to simply do "the right" thing for the environment.

Packing, because of its very nature function, becomes an integral element of the product. A prime concern regarding the packing is therefore to ensure that in any way endanger the health of the consumer [1]. This is particularly so with the packing used for cosmetic products, where there is an intimate contact with the product [2]. Assuming these conditions, there is still a question for using the material for packing bottles for liquids, considering the material that has the lowest impact on environmental considering the concept of Global Warming Potential.

In Alkaloid AD Skopje, the biggest pharmaceutical company in the Republic of Macedonia, the industry authorizes from environmental department helped in modeling as a simplification of reality minimizing the distortion. Modeling the life cycle of a group of a products from one department, impact characterization frameworks is developed and better evaluation for existing and new company's products is encouraged.

II. LYFE CYCLE ASSESMENT - LITERATURE REVIEW

2.1 Life Cycle Impact Assessment definitions

Life cycle (Impact) Assessment is a decision support tool within environmental management, which has been developed to compile assess the environmental implications of the product. LC(I)A refers to the sum of interactions that product has made with the environment, consisting of the pre-production, production, distribution, use, re-use, maintenance, recycling and end-of-life treatment processes [3].

2.2 General objectives and applications

General objectives elaborating LCA are:

- Defining framework of interactions between the given activity and the environment as integrally as possible;
- Contributing towards further understanding of the complexities occurring with the environment impacts of such activities;

- Provide all interested sides have their own power on further decision with information about the impact of such activities on the environment and about opportunities t improve environmental conditions.
The main applications are:
- Analyzing the origins of the problems related to a particular product;
- Comparing improvement variants of a given product;
- Designing new products;
- Choosing between a number of comparable products.

2.3 Methodology
The series of standards ISO 14040 covering the methodology of the tool as one of the most up-to-date documents on LCA methodology. Since the methodology is a yet not well enough advance to rank products according to their overall environmental performance, other criteria such as weight, reuse, energy, recovery and recyclability are the main factor taken into consideration at present.
Normally, four steps (phases) are distinguished in the Life Cycle Assessment Framework as shown in Fig. 1[4]:
Step 1. Goal and Scope Definition – preliminary definition of the technical framework of the study. It can include: application and specification of the products, respective life cycle to be considered, boundaries and allocation, impact assessment method and the format of the review [5].
Step 2. Life Cycle Inventory Analyses – involves data collection and calculation procedures to quantify relevant environmental interventions of a product in a life cycle model called "product system";
Step 3. Life Cycle Impact Assessment – evaluates the inventory inputs and outputs with regard to their environmental implication. Several steps are distinguished within the assessment: the classification (the assuming of inventory data to impact categories), the characterization (the weighting of the assigned inventory data within impact categories) and valuation (the aggregation to the impact categories by normalization and addition);
Step 4. Interpretation – summarizing the life cycle inventory analyses and analyses the available data with a view to providing a basis for appropriate decision making, relevant to the goal and scope of the LCIA exercise [5].

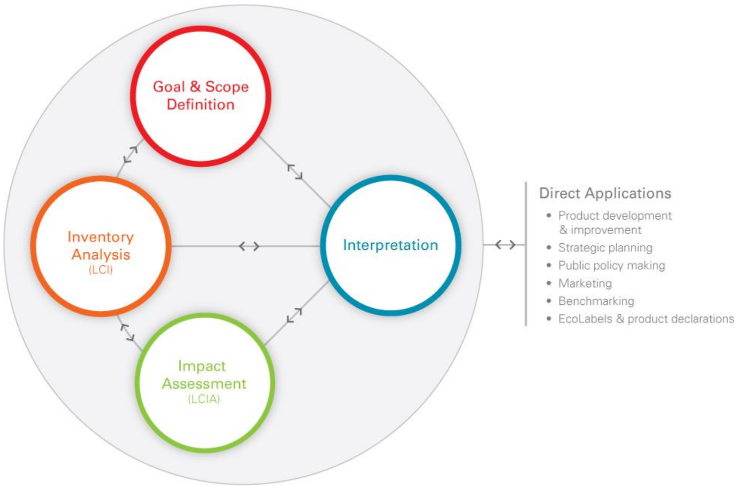

Figure 1 Life Cycle Assessment Framework

2.4 Concept of category indicators
Evaluation is the normative exercise in which the different impact categories are assigned significance weighting with a view of available alternative options. The valuation process may involve a structured weighting procedure or it may be performed on an ad hoc bases.
Fig. 2 illustrates the concept of category indicators based on environmental mechanism where each impact category has it's own impact agent and mechanism [6].

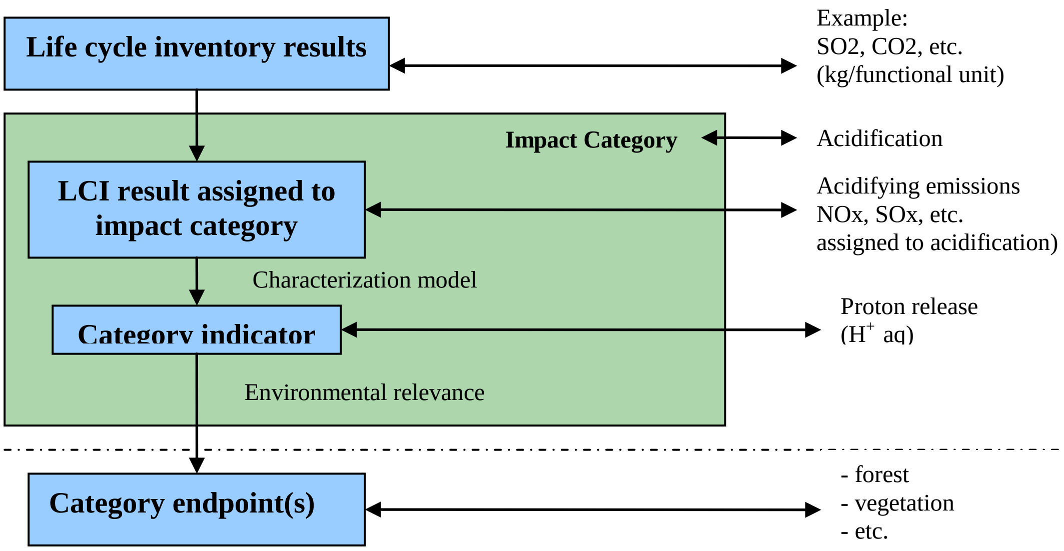

Figure 2 Concept of category indicators

Category end-points are defined as those attributes or aspects of the natural resources, environment or human health identified as being an issue of concern in the context of an LCA.
For each impact category the necessary components include:

- Identification of category end-points definition of the category indicator for a given end-point
- Identification of the appropriate LCI results that should be assigned to each impact category
- Identification of the characterization model and characterization factors.

This procedure is intended to facilitate collection, assignment and characterization modeling of LCI results, which are defined as the outcome of an LCI analysis that includes flows across the system boundary and provides the starting point for life cycle impact assessment. This procedure also helps to highlight the scientific and technical validity, assumptions, value choices and degrees of accuracy in the characterization model [7,8].
Table 1 provides an example, based on climate change, corresponding to the terms used in the standard ISO 14042 [6].

Table 1 Example of terms

Term	**Example**
Impact category	Climate change
LCI results	Greenhouse gases
Characterization model	IPCCa model
Category indicator	Infrared radioactive forcing (W/m2)
Characterization factor	Global warming potential for each greenhouse gas (kg CO2-equivalents/kg gas)
Indicator result	Kg of CO2-equivalents
Category endpoints	Coral reefs, forest, crops
Environmental reference	reference Degree of linkage between category indicator and category endpoint

2.5 Interpretations of the results
Life Cycle Interpretation provides a basis for decision making, relevant to the goal and scope definition of the conducted LCA. Relations with other phases and possible direct applications (for e.g. Product development and improvement, strategic planning, public policy making and marketing) are shown in Fig. 3 [7].

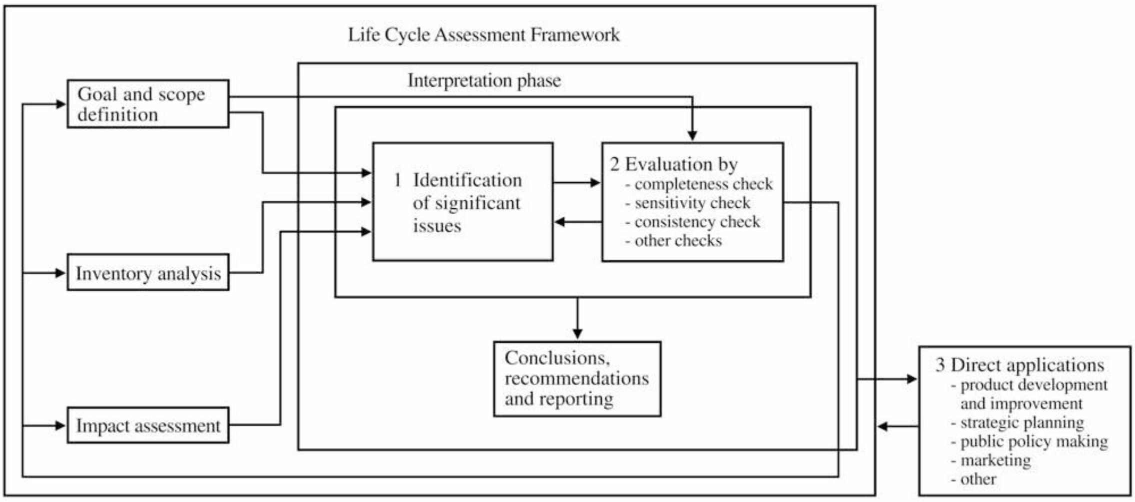

Figure 3 Interpretation and other LCA phases

LCA is one of the several environmental management techniques, e.g. risk assessment, environmental performance evaluation, environmental auditing, and environmental impact assessment [8,9].

2.6 LCIA role in packing system

Several major studies to analyse environmental impacts caused by production and use of packaging have been undertaken in Europe and North America. One of the earliest ones was carried out on behalf of the Swiss Federal Office of Environment and Landscape (BUWAL) in 1984, and updated in 1991. Another notable study, specifically on beverage packaging in the United Kingdom, was carried out by Dr. Ian Boustead on behalf of the UK Industry Council for Packaging and Environment (INCPEN) [1].

The eco-profiles of major packaging materials presented in this study, which include energy and raw material inputs, emissions to air and water and solid waste generation, are largely based on the studies carried out by Dr. Boustead and BUWAL included in SimaPro software [10].

The phases in the Life Cycle of packaging are as shown in Fig. 4 below and may be listed as follows:

- ✓ the production of raw materials and intermediate packaging materials;
- ✓ the manufacture of the packaging, the packing operations, and the distribution of the packed product;
- ✓ reuse of the packaging;
- ✓ disposal of the packaging 1) its recovery and use as a raw material, including composting, 2) incineration in incineration plants or as specific incineration, or 3) land filling.

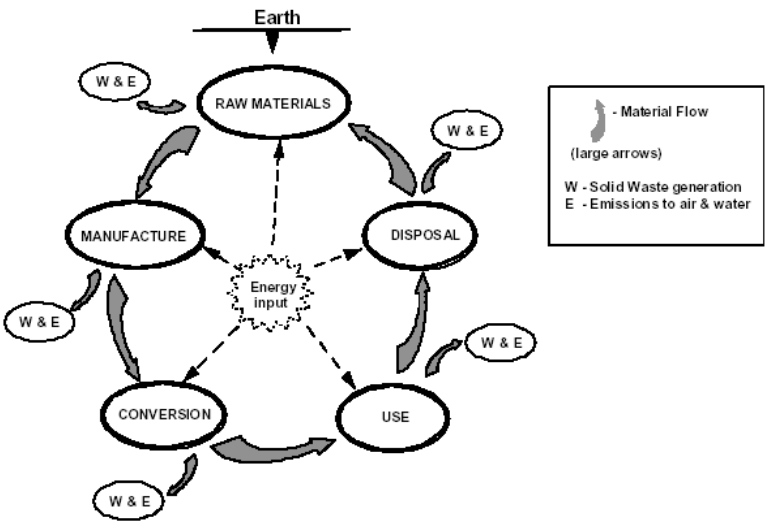

Figure 4 Typical life-cycle of product

LCA is one of the tools used to develop criteria for product selection eco-label awards including packaging, according to schemes being developed in the EU [9]. Since the methodology of LCA is as yet not well enough advanced to rank products according to their overall environmental performance, other criteria such as the weight, reuse, energy recovery and recyclability are the main factor taken into consideration at present.
LCA studies on consumer packaging have highlighted the major contribution to overall environmental impacts arising from consumers' own transport. In the past decades there has been a trend to locate supermarkets and superstores out of town, away from town centres.
This has meant that the shopper is obliged to make longer journey, normally by car, for weekly shopping. Depending on the amount of merchandize carried, such a journey can add significantly to overall environmental impacts [11].

III. CASE STUDY

3.1 Goal and scope definition
In order to see the possible alternatives according to effect of packing material the question asked was:

"Consuming the (cosmetic) mineral water is the better approach in terms of bottling from environmental point of view, assuming the global warming potential"

The goal for this LCIA study, from cradle-to-gate, is to compare the Life Cycle Impact Assessment of two alternatives for packing material of cosmetic mineral water.
The comparison considers the glass and PET bottles alternatives assuming:
A) Manufacturing process of packing material
B) Transportation of packing material from the facture to the pharmacy plant and
C) Transportation of packed (cosmetic) mineral water to the wholesaler.
The case is simplified for global warming potential.

3.2 Life cycle inventory analyses
The Eco-profile(s) of packing materials presented in the study, which include energy and raw material inputs, emissions to air and water and solid waste generation, are largely based on the studies carried out by Dr. Boustead and BUWAL. Material used for packing regarding the two alternatives are:
1. Glass bottles, used for (cosmetic) mineral water, are generally made either from clear or green glass. For the purposes of this study, it is assumed that clear glass is used overall, except for packed water where an equal split has been assumed between clear and green glass.
2. Plastic bottles, used for containment of (cosmetic) mineral water, are generally made of PET. Collation packing is assumed for 250 ml, 330 ml, 500 ml, 1000 ml, 1500 ml and 2000 ml bottles for packed product.
The weight of the average bottle for different bottle sizes is based on information from Excel's Packing Data store and in-house weighting by pharmaceutical company.
For the calculated data, the following assumptions are considered:
- Distance from the wholesaler is calculated by the average from all wholesalers distance; distance from the wholesalers to the retail trader is calculated as average from all retailers' distances; and distance from the bottle manufacturing to the bottling plant is considered as average from all manufacture distances.
- The bottled product is delivered from the bottling plant to the wholesaler in 16-t truck and from wholesaler to the retail by van 3.5t. The glass bottles are returned by van to the wholesaler and from wholesaler to the bottling plant in 16t truck. Empty glass bottles are delivered from the glass factory by 16t truck.
The calculation uses the information given in Table 1.

Table 1 Existed data

Data	Unit	Glass	PET
Bottle weight	g	237	20
Bottle capacity	l	0.25	0.33
Distance from bottle manufacturer to bottling plant	km	700	30
Distance from bottling plant to wholesaler	km	200	200
Distance from wholesaler to retail trader	km	50	50

3.3 Life Cycle Impact Assessment
Calculations take into account the life cycle of two types of bottles and the environmental loads for their production and transportation. The production and transport inventories as well as bottle weight are taken from BUWAL database in SimaPro software and the transport distances are calculated from the researching information.
-Production
The Environmental loads in the production processes, regarding GWP are given in the Table 2.

Table 2 EL in production process of bottles

EL	Units	Glass (1kg)	PET (1kg)
CO_2	kg	9.68E-01	3.45E+00
CH_4	kg	2.32E-03	1.17E-02

-Weighting of bottling material
Weighting of bottling material for two alternatives is given in the Table 3.

Table 3 Weighting of the bottling material

Bottling material	Weight	Units
Glass	60.61E-03	kg
PET	47.40E-03	kg

-Transport
Environmental loads considered regarding the transport of bottles, regarding GWP, are given in the Table 4

Table 4 EL in transport of bottles

EL	Units	Van (1tkm)	16-t Truck (1tkm)
CO_2	kg	1.54E+00	3.46E-01
CH_4	kg	2.61E-03	5.34E-04

Total EL for glass are given in the Table 5.

Table 5 Total EL for glass bottles

EL	Units	Glass	Glass bottle transport	Total
CO_2	kg	4.59E-02	4.35E-01	4.81E-01
CH_4	kg	1.10E-02	7.05E-04	8.15E-04

Total EL for PET are presented in Table 6.

Table 6 Total EL for PET bottles

EL	Units	PET	PET bottle transport	Total
CO_2	kg	2.09E-01	1.56E-01	3.65E-01
CH_4	kg	7.09E-04	2.53E-04	9.62E-04

3.4 Life Cycle impact assessment
Since the GWP is a matter of this study, the CO_2 and CH_4 emissions are assumed for characterization with the characterization factors and total global warming as CO_2 total equivalence in kg is calculated. The normalization and weighting that are used to compare the contribution of different impact categories are excluded from this study.

The results for total CO_2 total kg for Glass and PET bottling packages are given in Table 7.

Table 7 CO_2 total kg

CO_2 equivalent	Characterization factor	Glass	PET
CO_2	1	0.481	0.365
CH_4	62	0.0505	0.596
CO_2 total kg		0.532	0.961

IV. RESULTS AND RECOMMENDATION

Regarding the global warming potential is preferable to use glass bottle for (cosmetic) mineral water bottling/consuming in pharmaceutical company Alkaloid AD Skopje, considering the assumptions made and the data provided.
Given results are useful for interpretations only if all conditions are exactly the same as the study information.

Recommendations:
-If one wants to use more sized of packing bottles the analyses should be made considering the weighting of the material, e.g.1000 ml, 1500 ml, and 2000 ml.
- Other impacts, as acidification, should be assessed for environmental profile of packing material
- Also in this and other similar studies different fuel consumption for transport could be assumed.

The results of LCA do not allow the comparison and ranking of packing materials according to the overall environmental performance, because the types of emissions from the production of different materials differ from one to another and the LCA methodology is as yet not sufficiently developed to take account of this. At present, therefore, it is only meaningful to compare the performance for a given environmental parameter for example energy utilization, CO_2 emission, or acid emission to water, i.e. the way they are recovered after-use, reclaimed and reused, and finally disposed off.

V. CONCLUSION

Modeling the life cycle impact assessment of these two alternatives of packing material for a one group of a products, LCIA frameworks is developed and better understanding for evaluation of other company's products is encouraged. This will accomplish the relations between future designers, managers for strategic decisions and technologists to be involved in technology assessment for finding the packing material that has the lowest effect in Global Warming Potential, considering environmental impact.

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Biographies and Photographs

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