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Environmental Analysis of Packaging for Soft Drinks Using the Life Cycle Assessment Methodology

Marcelo Real Prado
Federal Technological University of Paraná—UTFPR, Curitiba-PR, Brazil
Georges Kaskantzis Neto
Federal University of Paraná—UFPR, Curitiba-PR, Brazil

The knowledge of a product's life cycle is the first step on the search of sustainable development. The life cycle assessment (LCA) is an important method because it allows an environment accounting, where the extraction of natural resources and energy of the nature are considered and the "returns" to the same one and allows in evaluating relative potential the environment impacts generated. The present work had as objective to make an analysis of material and energy flows of the life cycle of three types of packaging for soft drinks: glass bottles of 390 mL, aluminum cans of 350 mL, and bottles of PET of 2,000 mL. The study considered processes since the extraction of raw materials for production of the packaging until the stages of recycling, after the consumption of the soft drink. For the research, an inventory analysis followed the LCA methodology. The main critical points of generation of negative environmental impact during the life cycle of each packaging had been the identified and quantified data in this study. The consumption of natural resources like water and other raw materials and energy, the generation of atmospheric emissions, solid wastes and wastewaters had been the analyzed categories. The results showed that, in accordance with the scenes and defined variables, the most important conclusion was that the bottle of glass presented a less favorable scene to the environment in comparison with other packaging.

Keywords: life cycle assessment (LCA), inventory analysis, packaging, soft drinks, sustainable development

Introduction

Nowadays, consuming more and more means happiness. Stimulated by the need of selling their products, manufacturers spend large amounts of money on marketing to infuse this idea on the people. However, the irresponsible consumption is endangering the planet (Mourad, Garcia, & Vilhena, 2002).

When buying a product without worrying about the origin and the destiny, one is working together with the environment degradation, without being aware of it. Presently, as people have a stirred lifestyle, mainly in large cities, time is short and everyone wants do to everything in the fastest way.

As an example there are plastic, metal, and glass packaging used for soft drinks bottling, which go altogether to the garbage and even go with high toxic contents products, like electric cells, batteries,

Marcelo Real Prado, DSc., Life Cycle Assessment Researcher, Chemistry and Biology Department, Federal Technological University of Paraná

Georges Kaskantzis Neto, DSc., Management Environment Consultant, Chemical Engineering Department, Federal University of Paraná

Correspondence concerning this article should be addressed to Marcelo Real Prado, Deputado Heitor de Alencar Furtado Str., 4900, 81280-340 Curitiba-PR, Brazil. E-mail: mrealprado@utfpr.edu.br.

insecticides, and coatings (Coltro, 2003). On the other hand, there is consumption of energy and wastewater, because there is a feeling that it will never deceive (Brentrup, Kusters, Kuhlmann, & Lammel, 2004).

Industries have paid more attention to the environmental properties of their products also focusing on distinguishing them to enlarge the market share of the corporations. Several management techniques have been applied for the assessment of products' environmental impacts, such as, life cycle assessment (LCA), which studies the complex interaction between environment and product (Jönson, 1996; Chehebe, 1998).

This concept was known by LCA (Knight, Wolfe, & Poon, 1996; ABNT, 2009).

The life cycle study of a specific product includes since the stages of extraction of basics raw materials from the nature, which are constituent of the productive system, also including the industrial and consumption operations, until the stage of final disposal of the product when its lifetime has finished (SETAC, 1993; Jönson, 1996).

It is possible to settle the quantity of necessary natural resources, energy consumption, and waste derived from the process with output data from the LCA. Some works suppose LCA as a technique of resources and environmental profile analysis of the products used for the assessment and decision-making at a management level, focusing on improving product quality and environmental preservation.

The purpose of this work is an analysis of both energy and mass balance for top three sorts of packaging for soft drinks: aluminum can, PET bottles, and glass ones, with national data, using the LCA tool.

The project consisted in identifying and quantifying the main variables included on the packaging production process, like the use of energy and natural resources, besides emissions and waste produced during the whole life cycle of these packaging. The inventory subject includes showing critical points for environmental control as a way of helping on decision-making to optimize processes, changes on product focusing cleaner production and prevention of environmental pollution.

The process of LCA is too much complicated. There are models which are used together with other tools, like environmental audits, environmental diagnostics, as well as there are models which quantify environmental impact.

Methodology

The study can be divided into three stages: (1) description of the material sorts and included processes and the survey study of LCA of each one of the proposed packaging; (2) data collection in packaging companies; (3) in the literature and achieved information digest.

Definition of Study's Limits and Objectives

The main objective consisted in pointing out the critical points for environmental control as a way of helping on decision-making processes, changes on product focusing cleaner production, and prevention of environmental pollution.

Hereby, it intends to identify environmental improvement opportunities in the materials application and production process, to support the waste reduction and to plan the reusing and recycling.

The packaging for soft drinks showed in Table 1 was included in the study execution.

The limits definition of the life cycle study of each packaging is in accordance with the purpose of the work. The study included since the stages of raw-materials extraction to produce the packaging, the packaging not quite done (can, PET preform and glass bottle), its use in the soft drinks industry until the stage of recycling processes of each one of them.

Table 1

Bottling Capacity and Mass (Mean Values) of Studied Packaging

Type of packaging	Bottling capacity (mL)	Mass (g)	Number of packaging in accordance with the functional unity taken (1,000 L)
Glass bottle	290.0	386.2	3,448
Aluminum can	350.0	14.3	2,857
PET bottle	2,000.0	50.0	500

Study of Packaging Productive Processes

The description of the processes and materials types are in accordance with literature data and from consulting relevant enterprises (Silva, 2002).

In this study, a generic life cycle of a packaging for soft drink is composed of three stages: (1) the packaging production stage, which includes the raw materials extraction and the processes linked to its production; (2) the bottling stage, limited to the packaging preparing (cleaning) for soft drink bottling; and (3) the post-use and final destination stage (pertinent to the waste packaging guiding processes and recycling ones). The energy consumption and associated atmospheric pollutants emission were included in the stages of transport among distinct processes.

The achieved informations considered within significant, market-share leaders national enterprises (regarding to its production volume and its representativeness in the production sector), which some of these are multinational companies. The provided informations are in accordance with the productive capacity of each company.

The period of information searching was one year and a rough basis of 1,000 kg of material produced in each process. By this way, the difference between the inputs and outputs of each process gives 1,000 kg of product. The reference production plant of soft drinks is located at Sao Jose dos Pinhais, Parana State, Brazil.

Treatment of Information Gained From Literature and Field Work

The applied functional unity of 1,000 L of soft drink bottling capacity (of the studied packaging) for the assessment of environmental impacts and aspects and comparative study of the three chosen packaging.

The Working Up of Aspects Matrix

The relevance and extent in respect to potential effects they cause on the environment defined the choice of environmental aspects and the division into groups used on the identification and quantification of the environmental impacts of each studied process.

The identification of the most relevant variables of the product life cycle fed the working up of environmental aspects matrix.

To the former procedures, all of the life cycle processes of the studied packaging were included.

Comparative Analysis of the Results

A qualitative and quantitative analysis of the collected data during the fieldwork and in the literature related the results.

The qualitative analysis referred to the identification of environmental aspects related with the packaging productive processes.

The calculations for the achievement of the quantitative analysis referred to environmental-impacts, all the defined variables in the study, with the same rough basis, taking the settled functional unity as reference.

The energy, mass, and global balances were calculated for all processes of the packaging' LCA study after the working up of all processes issues and in accordance with the settled variables in the study.

The gained results allowed comparing and estimating which environmental impacts would be more relevant.

Results and Discussion

All the gained results are according to the sequence proposed by LCA.

The first part refers to the identification of the studied systems limits. Afterwards, the identified environmental aspects (qualitative study) and their quantification. The aspects and impacts assessment comes next. The discussion and interpretation of the results and the conclusion are in the final part.

Identification of the Systems Limits

For the achievement of an entire study, it was relevant to consider all processes that manage with the life cycle of the packaging used at the industry of soft drinks bottling. It was used the same procedure for the three sorts of packaging, like Silva (2002).

Because there is a great number of variables, like the raw-materials and waste generated from distinct processes, only the most relevant variables were included in this work, regarding to mass terms.

The plastic films, crates and other materials used for the transport and sales were not included, neither was the stage of soft drink bottling. The objective of the study referred to the packaging themselves, not to the bottling process of the product (soft drink), nor to the distinct ways of distribution and sales either.

Collected Data and Inventory Analysis

The first part of this stage consisted on identifying essential environmental aspects relevant to the study.

The study involved six main groups of environmental aspects: natural resources and secondary raw materials, energetic resources, atmospheric emissions, wastewater, and solid waste generated.

A relevant fact is that the choices and suppositions used in LCA studies are subjective in the most of the cases (for example, the systems limits, the selection of data sources, and the impact categories). Which means to say that the models can be limited to a predefined period (time) or to a local condition (Tibor & Feldman, 1990).

By analyzing the results, the consumption of natural resources is associated mainly to transport and to generation of steam from boilers. High consumption of electric power had relationship to the equipment's running.

The stages which include cleaning processes are essential responsible for high consumption of water and for generation of wastewater from the processes.

The fuel burning in the processes is the main source of atmospheric emissions and generates pollutants CO_2, CO, NO_x, SO_2, VOC's, particulates, among other ones (Fabi, 2004).

The loss of products, secondary packaging, and ash from fuel burning are examples more typical of solid wastes generated.

The last part of this stage consisted on the quantification of environmental aspects related to the life cycle processes of the three-studied packaging.

In accordance with the gained results, Table 2 and Figure 1 show the quantification summary of environmental aspects of the studied packaging life cycle.

Table 2

Brief Quantification of Environmental Aspects of the Studied Packaging Life Cycle in Accordance With the Settled Functional Unity

Environmental aspect	Glass bottles (recycling rate 25%)	Aluminium cans (recycling rate 90%)	Pet bottles (recycling rate 40%)
Material mass (kg)	1,331.70	40.83	25.00
NR—Natural resources (kg)	48.42	22.14	34.38
EC—Energy consumption (MJ)	3,638.64	2,808.23	2,768.83
WC—Water consumption (kg)	584.39	124.70	148.96
AE—Atmospheric emissions (kg)	29.99	6.70	9.29
WW—Wastewater (kg)	571.55	125.80	159.12
SW—Solid wastes (kg)	21.59	35.11	43.70

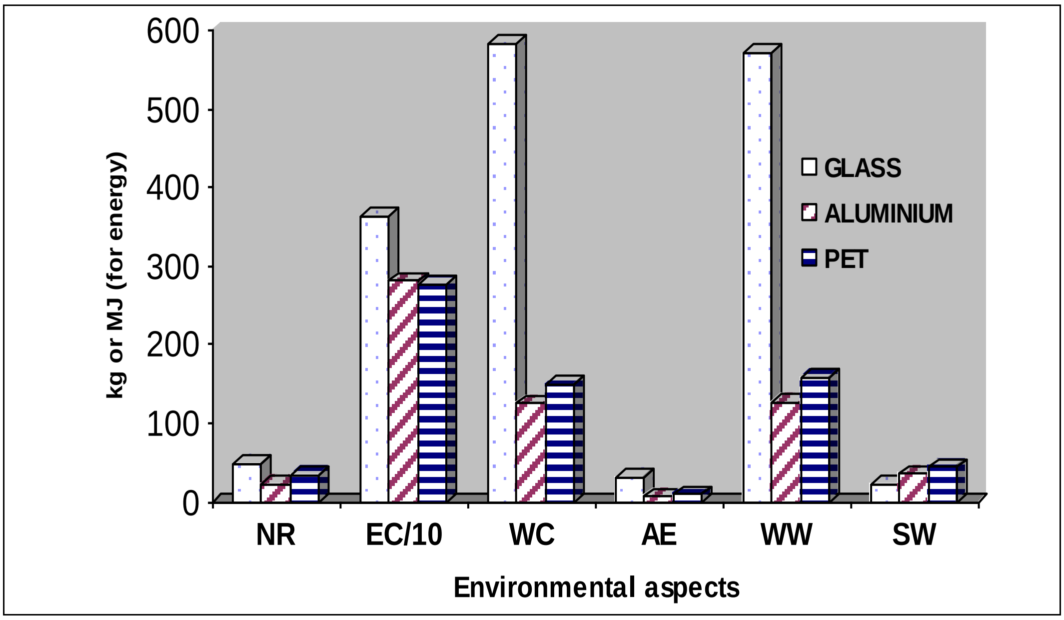

Figure 1. Quantification summary of environmental aspects of the studied packaging life cycle in accordance with the settled functional unity.

Figure 1 shows that the highest consumption of natural resources (NR) occurs in the glass bottles life cycle, which is 2.18 and 1.40 times higher than those consumed by aluminum cans and PET bottles, respectively.

The water consumption (WC) in the glass bottles life cycle is 4.69 times higher than that consumed by aluminum cans life cycle and 3.92 higher than that one consumed by PET bottles life cycle.

With regard to energy consumption (EC), the highest consumption occurs also in the glass bottles life cycle, which is 1.29 and 1.31 times higher than the energy consumption in the whole aluminum cans and PET bottles life cycles, respectively.

The emission of atmospheric pollutants (AE) is 4.48 and 3.23 times higher in the glass bottles life cycle, compared with both aluminum cans and PET bottles life cycles, respectively.

The glass bottles life cycle shows the highest wastewater generation (WW), which is 4.54 and 3.59 times higher than those generated from aluminum cans and PET bottles life cycles, respectively.

The solid wastes generation (SW), however, is the lowest in the glass bottles life cycle among the life cycles of the studied packaging. The highest generation of solid wastes occurs in the PET bottles life cycle, which is 2.02 times higher than that generated from glass bottles life cycle and 1.24 higher than the other one generated from aluminum cans life cycle.

Amongst all the studied life cycles, most of the stages of productive processes appear in different places. By this way, moving from one stage to another was computed in accordance with the kind of transport of included materials, distances, consumed fuel, and generated emissions from fuel burning.

Conclusions

In accordance with the studied systems, the results showed that glass bottle is the packaging that more contribute negatively to the environment. Aluminum can was the one that showed the best scenery, in other words, the lowest negative contribution to the environment.

The highest consumption of water and wastewater emission occurs in the glass bottle life cycle, due to reuse cycles and to its large constitution in the stage of recycling of the packaging life cycle.

It is relevant to highlight that, related to the consumption of natural resources and energy consumption, the PET bottle is the packaging that shows the worst scenery among the results. The same occurred for atmospheric emissions.

Amongst all top points in the production stages improvement, there are the reuse of water from bottles cleaning process and the reduction of process losses, where the quantities of generated solid wastes were remarkable in all sceneries.

The emission of VOC's for PET bottles is high in the stages of oil extraction and refining operations, which makes it necessary installing captivation systems of these emissions.

In the aluminum cans life cycle, the focus must be in the optimization of the alumina production stage, in order to reduce the quantity of generated industrial waste.

With regard to the study methodology for LCA, the data collection is too complex and it requires time to gain, to analyze, and to comprehend. Besides, it is relevant to emphasize that the results achieved here show the reality of a national industry, in accordance with the pre-settled referential.

The results gained in this study referred exclusively to the proposed sceneries, pre-settled reflections, and variables. Another remark is that these results have an "expire date", as for it is an LCA study. That means to say the achieved results can vary in case of scenery and variables changes, besides time period itself.

The products LCA appear as a real option for industry and society, with the purpose of knowing the product and its influence over environment better.

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