QUANTITATIVE EVALUATION OF ENVIRONMENTAL IMPACT THROUGH INVESTIGATION
OF PLASTIC PRODUCTS

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ABSTRACT

The manufacturing process of a product produces emissions detrimental to air, water and soil during its entire life from raw material extraction to the final disposal. The emissions have harmful effects at local, regional and global levels. Environmental Impact Assessment (EIA) is used to identify the detrimental effect or environmental impacts of a project prior to its start. Life Cycle Analysis (LCA) is one of the tools that can help designers to understand the environmental impacts associated with their products, processes and activities. The work includes the scientific approach of Life Cycle Assessment (LCA) for environmental impact evaluation of typical consumer plastic products used in day to day life. Eco Indicator 99 methodologies are used as an overall approach for quantitative evaluation of environmental impact. It is being used very often by designers. The principal goal of the work is to evaluate the emissions associated under two heads, i.e. damage to eco system quality (climate change, ozone layer, acidification/ eutrophication, ecotoxicity) and damage to human health (carcinogen, respiratory organics, respiratory inorganic) with the production of plastics products.

Key Words: Environmental Impact Assessment (EIA), Life Cycle Analysis (LCA), Life Cycle Inventory, Environmental Impact Evaluation (EIE), Decision-making, Planning tool, Emissions, Plastic products

INTRODUCTION

The human activity has an impact on the environment in which we live. The environment has some capacity to absorb the emissions so emitted to a certain level without lasting damage. If human activities exceed the threshold level of emission with increasing frequency, then it would diminishing the quality of environment the world in which we now live and threatening the well-being of future generations. A part of this impact is derived from the products, starting right from its origin to the disposal. The environmental performance of products and processes has become a key issue, which is why some companies are investigating ways to minimize their effects on the environment. The materials (and the energy needed to make and shape them) are drawn from natural resources: ore bodies, mineral deposits and fossil hydrocarbons. The Earth’s resources are limited and the demands made on natural resources by manufacture increasing since 18th centuries and demand the rate of new discoveries always outpacing the rate of consumption. Plastics are generally produced from fossil fuels, which are gradually depleting. The production process itself involves energy consumption and further resource depletion. During production, emissions may cause pollution to water, air or soil. This type of investigation of products may bring economic advantages resulting into reduction of material and energy consumption. Environment friendly products are in demand due to awareness of consumers, moreover marketing advantage.

The life cycle inventories of the water pipe
as a hard PVC product and the agricultural film as a soft PVC product were analyzed and the comparison with the alternative products of polyethylene and polyester was investigated with the viewpoint of environment. This LCI applied to evaluated 12-ounce water bottle. The three types of environmental burdens were found helpful in distinguishing the analysis results (i) energy requirements (ii) solid waste generation and (iii) greenhouse gas emissions. A life cycle assessment was conducted to evaluate the total environmental burdens of the yogurt Product Delivery System (PDS) for Stonyfield Farm. The plastics High Density Polyethylene (HDPE) became standard materials in the manufacturing industries due to their high adaptability and cheap cost.

In this work three products of plastic (HDPE) are taken as case study for investigating the quantitative environmental impact evaluation.

LCA

Life Cycle Analysis (LCA) is one such tool that can help companies to understand the environmental impacts associated with their products, processes and activities. The analysis evolves as the methodology rapidly adopted by manufacturers and service organizations. It opens new perspectives expanding the debate over environmentally sound products and processes. The goal of LCA is not to arrive at the answer but, rather, to provide important inputs to a broader strategic planning process.

Components of Life Cycle Analysis

Life cycle analysis takes a systems approach for evaluating the environmental consequences of a particular product, process or activity from cradle to grave. Ideally, a complete analysis would include three separate but interrelated components an inventory analysis an impact analysis and an improvement analysis. By taking a snapshot of the entire life cycle of a product from extraction of raw materials to the final disposal, LCA is used to assess the impact of each component process systematically.

The assessment procedure involves three main stages the first stage is the collection of data and the second is the evaluation and the third is the interpretation of that data. The purpose of life cycle studies is to assess the environmental impacts of potential product substitutions.

LCI

A Life Cycle Inventory (LCI) is an environmental profile that expresses environmental burdens from the perspective of energy consumption, solid waste generation atmospheric emissions and waterborne emissions.

AIMS AND OBJECTIVES

The objective of this work is the quantitative evaluation of the environmental impact of typical plastic products using Life Cycle Assessment (LCA) methods. The principal goal is to evaluate the emissions associated with the various stages of production of common household products made from plastic (HDPE). The analysis covers mainly two types of damages, i.e. Eco System quality damages and human health damages for the following three main stages for each product:

i) Raw material acquisition
ii) Production of the raw materials
iii) Production of the product

The LCA method Eco-Indicator 99 has been used to develop a better understanding about the environmental impact on various impact categories.

METHODOLOGY

Methodology of LCA

In this work, we have done investigation of the products manufactured by plastic (HDPE). The LCA method Eco Indicator 99 has been used for the quantitative evaluation of environmental impact of various impact categories under eco system quality damages and human health damages. Three consumer products under analysis are the ones which are used in large quantities in day to day life i.e. oil can, chair and dust bin. The analysis is done for the quantity of 100 nos. of each product. In the life cycle assessment, the environmentally relevant input and output flows of the life of the products have been studied. The environmental impacts caused by them are calculated and evaluated. ISO 14040 defines a life cycle as comprising of four phases as shown in Fig. 1.

Phases of LCA

Goal and Scope Assessment

The purpose of the study is to calculate the total environmental burdens arising due to the different stages of a product life cycle. The goal and scope should address the overall
approach used to evaluate the impact categories for the stages of the product (three main stages – raw material acquisition, raw material manufacturing and part manufacturing). The system determines which unit processes are included in the LCA and must reflect the goal of the study.

In this interpretation phase, the results are analyzed in relation to the goal of the study. Conclusions are drawn and recommendations are provided based on the findings of the preceding phases. The conclusions should be compatible with the goals and quality of the study. The overall methodology for quantitative evaluation of environmental impact is described in Fig. 2.

**Case study**

The quantitative evaluation of environmental impact for the three products is carried out by the method Eco-Indicator 99. The details of the products considered for the study are as shown in Table 1.

**Table 1 : Capacity and weight detail of the products**

<table>
<thead>
<tr>
<th>Product</th>
<th>Capacity</th>
<th>Weight in gms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil Can</td>
<td>15 ltrs</td>
<td>596</td>
</tr>
<tr>
<td>Chair</td>
<td>80 kgs</td>
<td>1850</td>
</tr>
<tr>
<td>Dust Bin</td>
<td>10 kgs</td>
<td>240</td>
</tr>
</tbody>
</table>

The products have been studied for the three main stages of the life cycle namely

- Stage I - Raw Material Acquisition
- Stage II - Raw Material Manufacturing
- Stage III - Part Manufacturing

The emissions have been evaluated for the different impact categories as per Eco-Indicator 99 under the two aspects as:

- Eco system quality damages:
  - Acidification/ Eutrophication (AE)
  - Climate Change (CC)
  - Ecotoxicity (ET)
  - Ozone Layer (OL)

- Human health damages:
  - For Carcinogen (CR)
  - Respiratory Inorganics (RI)
  - Respiratory Organics (RO),

**RESULTS AND DISCUSSION**

The results obtained by the analysis, are presented graphically in Fig. 3 as matrix form. The three main stages of life as A, B and C are presented under the two aspects eco system quality damages and human health damages. The different impact categories of particular damage are on abscissa and the emissions calculated are on ordinates.

The range of emissions obtained for various impact categories is very large. The emissions of some impact categories have very less values as compared to other. So they are not visible on the regular scale of graph. Hence logarithmic scale is used to present the values of emissions. The ordinates starts from zero, so the impact category has decimal values of emissions are shown on negative side i.e. downside to abscissa.
Fig. 2: Framework of the system for analysis of products

Fig. 3: Eco system quality damages and human health damages of typical plastic products for three main stages of life cycle as per LCA method Eco Indicator 99
Table 2: Presentation of relative emissions impacts (in %) for both types of damages

<table>
<thead>
<tr>
<th>S/N</th>
<th>Impact category</th>
<th>Stage-I</th>
<th>Stage-II</th>
<th>Stage-III</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Oil can</td>
<td>Chair</td>
<td>Dust bin</td>
<td>Oil can</td>
</tr>
<tr>
<td>1.</td>
<td>AE</td>
<td>6</td>
<td>19</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>2.</td>
<td>CC</td>
<td>12</td>
<td>36</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>3.</td>
<td>ET</td>
<td>18</td>
<td>57</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>4.</td>
<td>OL</td>
<td>*</td>
<td>1</td>
<td>*</td>
<td>1</td>
</tr>
</tbody>
</table>

Human health damages

<table>
<thead>
<tr>
<th>S/N</th>
<th>Impact category</th>
<th>Stage-I</th>
<th>Stage-II</th>
<th>Stage-III</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Oil can</td>
<td>Chair</td>
<td>Dust bin</td>
<td>Oil can</td>
</tr>
<tr>
<td>1.</td>
<td>CR</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>2.</td>
<td>RI</td>
<td>18</td>
<td>55</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>3.</td>
<td>RO</td>
<td>10</td>
<td>30</td>
<td>4</td>
<td>12</td>
</tr>
</tbody>
</table>

**-** Very very less as compared to other

**CONCLUSION**

Under eco system quality damages, the acidification and Eutrophication, eco toxicity are the dominating categories. They have very large impact on the environment as compared to other categories - climate change and ozone layer during all the three stages of life. The impact on ozone layer is more as compared to climate change in part manufacturing stage as compared to raw material acquisition and vice-versa, but during material manufacturing stage both are on almost same scale (approx). Under human health damages, the respiratory organics has very less impact on human health as compared to other impact categories – carcinogen and respiratory inorganics for all three stages of life cycle. The impact of carcinogen on human health is very large as compared to respiratory inorganics in part manufacturing stage as compared to raw material acquisition stage and vice-versa, but during material manufacturing stage both are on almost same scale (approx).

If all the impact categories as per Eco-Indicator 99 are grouped for all the three stages taken together then relative emission impacts can be presented into a tabular form. The relative impacts (in %) of eco system quality damages and the impacts of human health damages are presented in the Table 2.

**REFERENCES**


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