# The Assessment of the Environmental Impact of Selected Plastics

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## Abstract

*The present article deals with a method of the environmental Life Cycle Assessment (LCA) as a tool for the evaluation of environmental burden of selected products. The assessment of the life cycle of individual products should be carried out while considering emissions released during production, use and disposal of products and during processes of raw material extraction, production of materials and energy, auxiliary processes or sub-processes.*

**Keywords:** LCA; plastics; environment; recycling;

## 1. Introduction

In modern times, an increasing emphasis has been put on the development of environment-friendly technologies which are not only more energy-efficient, but they also eliminate the undesired environmental impact of active equipment or production and use of products [4].

A population growth constantly endangers reserves of fossil materials, and rapidly growing environmental pollution caused that scientists began to deal with ecological balance.

The most important point of view in assessing the environmental impact is energy consumption which is associated with a limited amount of energy sources. Energy consumption is also accompanied by negative effects, such as atmospheric emissions that contribute to the formation of acid rains, smog and greenhouse effect.

## 2. Life Cycle Assessment

An analytical method of environmental management referred to as the Life Cycle Assessment (LCA) has been increasingly applied all over the world. This approach analyses the environmental impact of products and services during their life cycles. The environmental impact of processes of raw material extraction, production, implementation and disposal of production waste are also taken into account. LCA may be defined as the collection and assessment of input and output data and potential effects of products on the environment during their entire life cycles.

The output of the method is the environmental assessment of the impact of a given product on the environment (environmental certification or environmental labelling of products). The main purpose of these outputs is to prevent environmental pollution, support the development of production and consumption of products with less negative effects during their entire service lives, provide true information on their environmental impact, all with the aim to influence not only producers but also consumers.

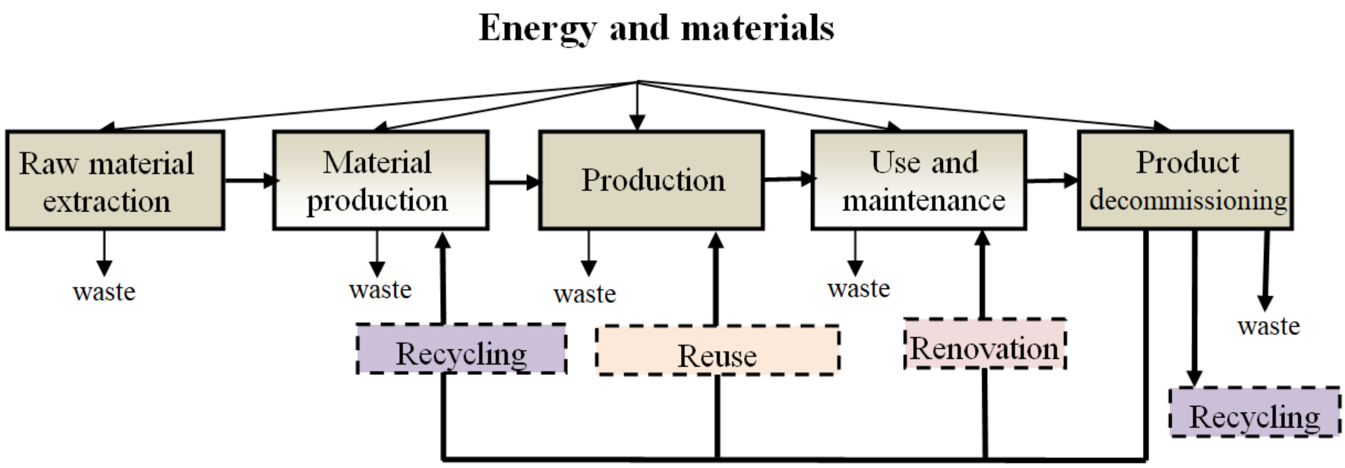


Figure 1. Product life cycle.

A life cycle assessment study consists of four phases: *goal and scope definition, inventory analysis, impact assessment and interpretation of a life cycle.*

The first stage includes defining the size of the product life cycle which will be subjected to the assessment and the purpose of the assessment. The inventory analysis includes drawing all input and output streams associated with the product, while the inputs represent water, energy and materials taken out of the environment and the outputs represent emissions and waste put into the air, soil and water. The third phase represents the calculated results of indicators of all impact categories and the evaluation of their mutual significance by normalisation or weighting. The result of the impact assessment is usually a table listing all the impacts. The last phase comprises of a systematic procedure aimed at identification, quantification, control and evaluation of information from the results of the life cycle inventory analysis and the assessment of the life cycle impact. The result of the interpretation phase is a set of conclusions and recommendations for the study.

At present, plastic materials have been increasingly used because plastics have proved to offer many applications and they meet the requirement of high quality for a relatively low price. Therefore, it is necessary to understand the essence of these materials, primarily their advantages and disadvantages, as well as their negative environmental impact.

### *2.1 Beginning of the life cycle of plastics*

Plastics intervene with the environment in all stages of their life cycle, including the extraction of crude oil and gas, production, transport and final waste disposal. It is very difficult to assess categorically which one of the plastic materials is more environmental-friendly. However, it is absolutely certain that chlorine-containing plastics very often have a negative environmental impact.

The life cycle of a plastic material begins as early as the excavation of raw materials and consumption of energy required for the production of a plastic material.

Plastics are produced from crude oil which belongs to non-renewable sources of energy; moreover, oil treatment processes run in refineries which are not very ecological. The energy used for crude oil refining is taken from non-renewable sources. Production of plastics as such may be accompanied by the environmental pollution, in particular through leakage of harmful materials to air, soil and water.

Production of fluorinated polymers has been widely criticised due to the associated use of perfluorooctanoic acid which is toxic and even suspected of carcinogenicity. PTEE may degrade, at high temperatures, into toxic products which are very hard to decompose and accumulate in the food chain.

Another most frequently used plastic material is polyvinylchloride (PVC). Unfortunately, it is one of the worst plastic materials for the environment. It has been widely used in the food industry (various types of packaging, bottles etc.), building industry (window frames, cables, pipes etc.), automotive industry, as well as medicine, power industry and telecommunications.

Not only the production of this plastic materials is hazardous because it is accompanied with the formation of one of the most hazardous substances - dioxin, but also harmful additives escape to the environment during the use and disposal of PVC.

As PVC is very difficult to recycle, majority of this material ends at waste dumps or in incineration plants. Dioxins are produced during the PVC production and combustion, and these processes not only pollute the environment but also endanger human health.

One of the hazardous chemicals contained in PVC is phthalate, a plasticiser which is the main component of this plastic material. Other hazardous components include heavy-metal-based colorants, flame retardants and bound chlorine which is very dangerous when these plastics burn.

Polystyrene is also a plastic material, production of which is very unfriendly to the environment, but its use is being increasingly popular. This material is very hazardous because it contains toxic substances - styrene and benzene - neurotoxins and probably also carcinogens. When polystyrene is in contact with a hot food or beverage, styrene is released and then it enters a human organism and causes serious health problems.

### *2.2 Recycling of plastics*

Recycling is a reuse of previously used materials and products. This process reduces the consumption of natural materials, reduces the quantity of dumped waste and consumed energy, and thus contributes to the reduction of greenhouse gases.

Prior to the recycling process, it is necessary to thoroughly sort plastic wastes.

Recycling of plastics has a positive effect on the reduction of environmental burden and leads to reduction of the amount of dumped waste (decomposition of plastic materials at dumps lasts several decades). However, it also has a positive impact on crude oil extraction and leads to savings in purchase cost of this material.

Nevertheless, this process of recovery of plastics is not very ecological because it requires a lot of energy, water, transport etc. Plastics may only be recycled into lower-quality products. Despite such negative aspects, recycling is currently one of the most optimal methods of the disposal of plastic materials.

## 3. Thermal processing of waste

With regard to the fact that not all plastic materials may be recycled, it is necessary to deal with their storage or processing. Dumping larger quantities of waste, however, has a negative environmental impact in areas where such dumps are established, and in the case of uncontrolled or older dumps, the soil and underground water become seriously polluted. One of the potential methods of the disposal of such waste is thermal processing in which syngas is the resultant product. Such processing is usually carried out in incineration plants or plasma reactors where heat facilitates the decomposition of more complex hydrocarbons into basic compounds. The process output is synthetic gas, mostly consisting of hydrogen, methane, carbon dioxide and carbon monoxide.

As a majority of non-recyclable plastics end in combined communal waste, such waste is processed without sorting organic residues from plastics, whereas these plastics represent a significant part of the waste. Table 1 shows the percentages of individual components of syngas produced by processing various types of communal waste, while non-recyclable plastics in a plasma reactor reprersent a significantly high percentage.

**Table 1. Compositions of various syngas components**

| Folder | Composition of synthetic gas samples | | | |
|---|---|---|---|---|
| | RDF (obj. %) | Municipal waste 1 (obj. %) | Municipal waste 2 (obj. %) | Municipal waste 3 (obj. %) |
| **Methane ($CH_4$)** | 0,26 | 8,59 | 4,77 | 2,54 |
| **Hydrogen ($H_2$)** | 50,9 | 44,5 | 48,9 | 30,3 |
| **Oxygen ($O_2$)** | 0,03 | 0,16 | 0,11 | 0,74 |
| **Nitrogen ($N_2$)** | 4,25 | 6,03 | 6,61 | 15,9 |
| **Carbon dioxide ($CO_2$)** | 1,1 | 6,6 | 1,66 | 2,42 |
| **Carbon monoxide (CO)** | 43,5 | 32,5 | 37,1 | 47,3 |
| **Ethene ($C_2H_4$)** | 0,006 | 0,97 | 0,49 | 0,52 |
| **Ethane ($C_2H_6$)** | 0,001 | 0,055 | 0,031 | 0,023 |
| **Ethin ($C_2H_2$)** | 0,003 | 0,42 | 0,24 | 0,15 |
| **Σ $C_3$ hydrocarbons** | 0,005 | 0,011 | 0,004 | 0,004 |
| **Σ $C_4$ hydrocarbons** | 0,001 | 0,0099 | 0,004 | 0,005 |
| **Σ $C_{5\text{-}8}$ hydrocarbons** | 0,001 | 0,17 | 0,12 | 0,09 |
| **Calorific value ($MJ \cdot m^{-3}$)** | 11,1 | 13,12 | 12,31 | 10,71 |
| **Expected volume production ($m^3 \cdot kg^{-1}$)** | 1,843 | 1,069 | 0,973 | 0,404 |

Results of measurements in a plasma reactor indicate a high percentage primarily of hydrogen and carbon monoxide. These gases belong to materials with a great potential of energy recovery. Following the processing of carbon monoxide, as described by Equation (1), it is possible to extract a higher percentage of hydrogen which is projected to represent an important energy carrier in future, not only for the automotive industry but also for other industries.

$$CO + H_2O \Longleftrightarrow CO_2 + H_2 \quad (1)$$

A described reaction runs in a WGS reactor in the presence of iron-oxide-based catalysers at higher temperatures (370–420 °C) or lower temperatures (200–250 °C) using $Cu/ZnO/Al_2O_3$-based catalysers.

## 3. Conclusion

The evaluation of issues regarding environmental-friendly use and production of plastics while applying the LCA method is a rather complicated and time-consuming process. This is caused by the complexity of the whole process in which it takes a lot of time to proceed from the extraction of raw materials, through subsequent processing, production and use, up to the environmental-friendly disposal of products after their service life terminates.

However, it is currently one of the tools facilitating evaluation and assessment of how much energy and materials a particular plastic material consumes during its life cycle, how much it pollutes the environment and how much waste is produced in the process.

## 4. Acknowledgement

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