LCA of thermoplastics recycling

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ABSTRACT

Thermoplastics make up roughly 80% of the plastics produced today. There are hundreds of types of them and new variations are being developed. But not all thermoplastics are recyclable. The most commonly recycled thermoplastics are PE, PP, PS and PVC.

In this study, real data from the industry is used in the analysis of the environmental impact of plastics recycling by means of the application of the LCA methodology to the products and processes involved in mechanical plastic recycling of black HDPE for extrusion or blow moulding coming from industrial scrap. The results obtained were compared with assessments made by other authors and with the impact associated with the manufacturing of virgin thermoplastic according to databases. The interpretation of these comparisons leads us to conclude that the recycling process has been optimised over the past years, thus reducing its environmental impact. Furthermore, the clear advantages from the eco-efficiency viewpoint of plastic recycling against direct manufacturing from petroleum are highlighted.

Introduction

In the past 30 years, global plastic consumption has multiplied by 10, reaching an estimated value of 100 M tonnes per year. However, this technological development has not foreseen the implications of product recycling. The recycling of these materials is a must given their limited or no biodegradability and the fact that they cause the depletion of a non-renewable resource like petroleum (they account for 4% of Europe's total petroleum consumption), in addition to their visual impact on landfills.

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The most widespread recycling process is mechanical recycling, by which plastics are recovered from the waste stream. Plastics undergo sorting, shredding and washing processes to yield plastic flakes, pellets or powder. The material hence obtained is ready for its subsequent transformation into new products. This type of recycling is the best option from the environmental perspective when compared to chemical, physicochemical or energy recovery recycling, although it is not optimised from the economic viewpoint [1].

Goal and scope

The goal of this study is to perform the life cycle assessment of the products and processes involved in the mechanical recycling of thermoplastic materials coming from industrial waste. The results are then compared to data provided by recycling machinery manufacturers and bibliographical data from other authors. Furthermore, the impacts of recycling are compared to those associated with the production of virgin plastics.

Life Cycle Inventory (LCI)

1. Recycling industry

Real data from the industry were used in the analysis of the environmental impact of plastics recycling through the application of the LCA methodology to the products and processes involved in mechanical plastic recycling from industrial scrap for extrusion or blow moulding of black HDPE.

Figure 1 shows the flux diagram of black HDPE along with the amounts of materials and energy used. A mass and energy balance was performed for system inputs and outputs. In this case, transport of HDPE from plastic processing plants to recycling plants has been taken into account as well.

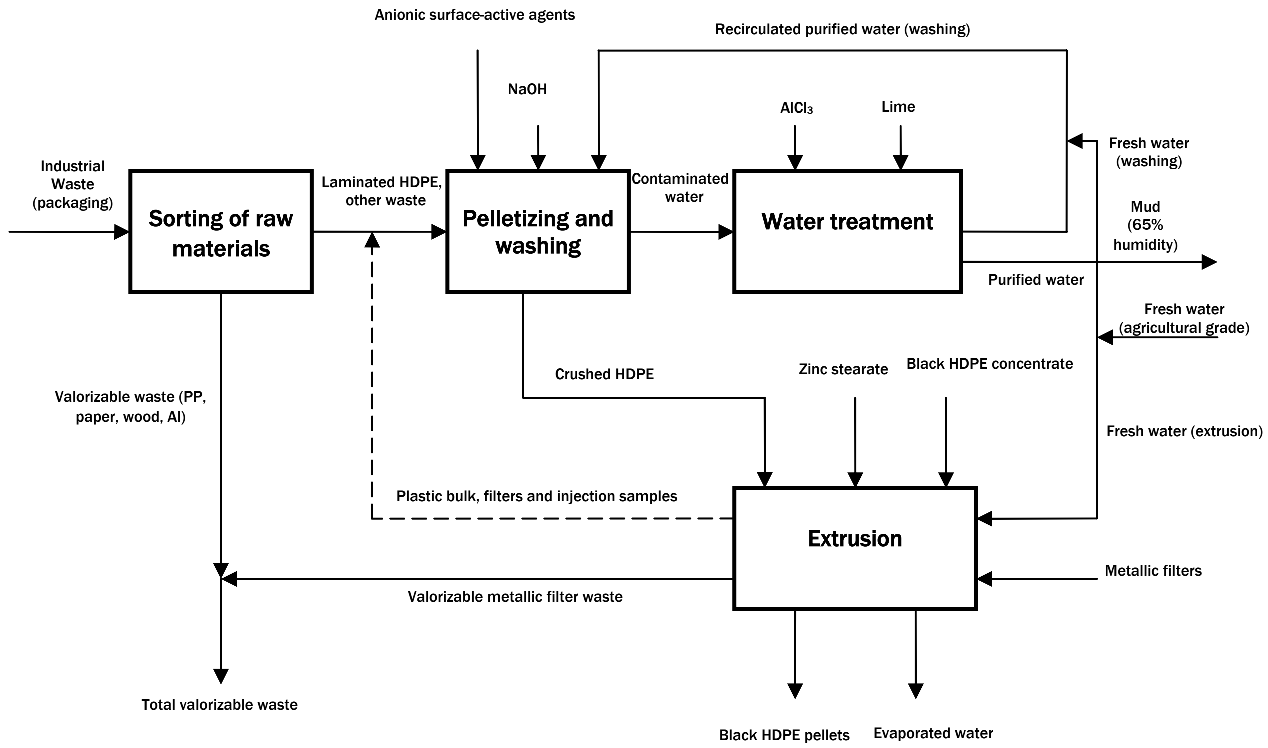

Figure 1: Flow diagram of black HDPE recycling

2. Bibliographical data

i) White et al.[2] carried out a LCI on the integrated management of solid waste –including plastics-, analysing the inputs and outputs of recycling processes in order to assess their environmental impact. The data available come from an internal report [3] of a recycling plant, which provides detailed information on mass and energy flows in the process of recycling rigid HDPE bottles.

ii) Perugini et al. [4] published a life cycle assessment of mechanical recycling of plastic waste as a follow-up to a previous study [5]. Their assessment encompassed a comprehensive set of Italian firms dedicated to the mechanical recycling of plastic, which they compared from the environmental point of view to other alternatives such as incineration or mere landfilling. They also analysed the impact caused by other innovative post-recycling processes such as low-temperature pyrolysis or high-pressure hydrogenation, confirming these processes are more environmentally friendly than conventional ones.
The inventory data collected by the authors corresponding to material and energy flows are related to the production of recycled PET and polyethylene from plastic waste. For this study, only the data related to the production of 1 kg of mechanically recycled polyethylene were taken into account.

3. Manufacturers of recycling machinery

The recycling process comprises fragmenting or shredding plastic waste, heating above melting point, extruding and finally pelletizing plastic. In our case, solely energy consumption figures of machinery –extracted from technical data provided by machinery manufacturers- were considered, dismissing additives, transport, lubricants, etc. Specific consumption figures were obtained from production rates and required power inputs.
The firm Schulz & Partner (Heilbronn, Germany) possesses a PE or PP washing and drying line model TC 500 by Italian manufacturer TECNOFER, which they use to process plastic waste prior to extrusion and pelletizing. Plastic waste enters the line as film or bales, and comes out as clean, dry bits ready for extrusion. Considering its processing capacity and total power of all elements in the line, a specific consumption figure was obtained per weight unit of PP or PE.

Technical data for extrusion and subsequent pelletizing were obtained from Austrian manufacturer Artec. A mean value from several extruding machines was considered.
These data were used to estimate total energy consumption of the process of plastic recycling.

4. Production of virgin HDPE
The data regarding the manufacturing of HDPE come from the following databases, found in Simapro 7.0 impact assessment software:

- Buwal 250 [6].
- Ecoinvent [7].
- PlasticsEurope (Association of Plastics Manufacturers in Europe) [8].

Impact assessment
The following table shows the environmental impact of each of the processes analysed after inventory data collection. The impact assessment methodology followed was CML 2 baseline 2000, as developed by the Institute of Environmental Sciences in Leiden (The Netherlands). The normalisation factor set employed corresponds to Western Europe in 1995 [9].

Table 1: Normalised eco-profile of 1 kg of HDPE (recycling or manufacturing)

	Abiotic resource depletion	**Global warming GWP100**	**Acidification**	**Eutrophication**
Recycling industry	1,15E-14	5,82E-14	6,13E-14	8,06E-15
White et al. [2]	3,63E-14	3,25E-13	4,10E-13	4,80E-14
Perugini et al. [4]	1,38E-14	9,43E-14	1,15E-13	1,12E-14
Machinery industry	1,45E-14	9,89E-14	1,21E-13	1,18E-14
Buwal 250 [6]	2,04E-13	4,47E-13	4,47E-13	1,05E-13
Ecoinvent [7]	2,08E-13	3,94E-13	7,83E-13	1,09E-13
PlasticsEurope [8]	2,15E-13	3,91E-13	7,82E-13	1,04E-13

Figures 2 and 3 illustrate the comparison between the environmental impact caused by the recycling process studied and the impact caused by recycling HDPE derived from petroleum.
The differences between the data from the recycling firm and those from machinery firms are attributed to the fact that the latter offer machinery capable of recycling plastics with higher melting points than those of HDPE, whereas the recycling firm possessed one line exclusively dedicated to the recycling of HDPE, with highly optimised shredding and washing processes.
The inventory compiled by Perugini et al. [4] comes from Italian polyethylene recycling firms, just like the one considered. The similarities of the impacts in both cases can be appreciated.
When comparing results with White et al. [2], it must be noted that their data dates back to the 1990s, when plastic recycling was not as optimised and profitable as it is today. This leads to high environmental impact results, as observed in figure 2.

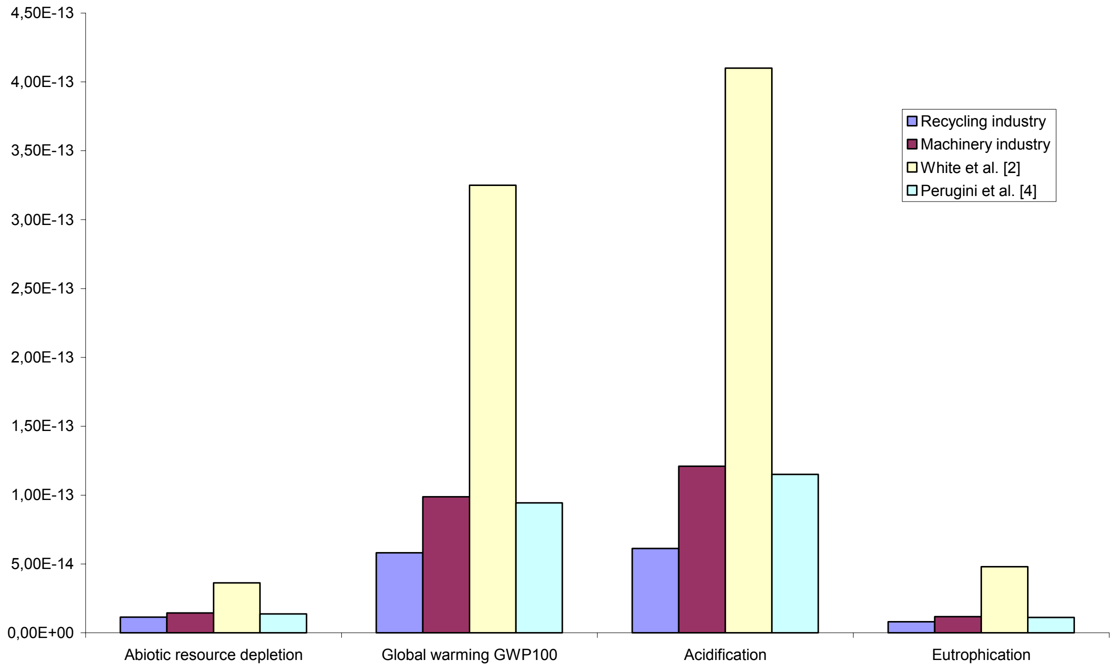

Figure 2: Eco-profile of recycling 1 kg of HDPE, by data source

The recycling of HDPE is compared to the production of virgin HDPE in figure 3. Recycled HDPE is clearly more eco-efficient.

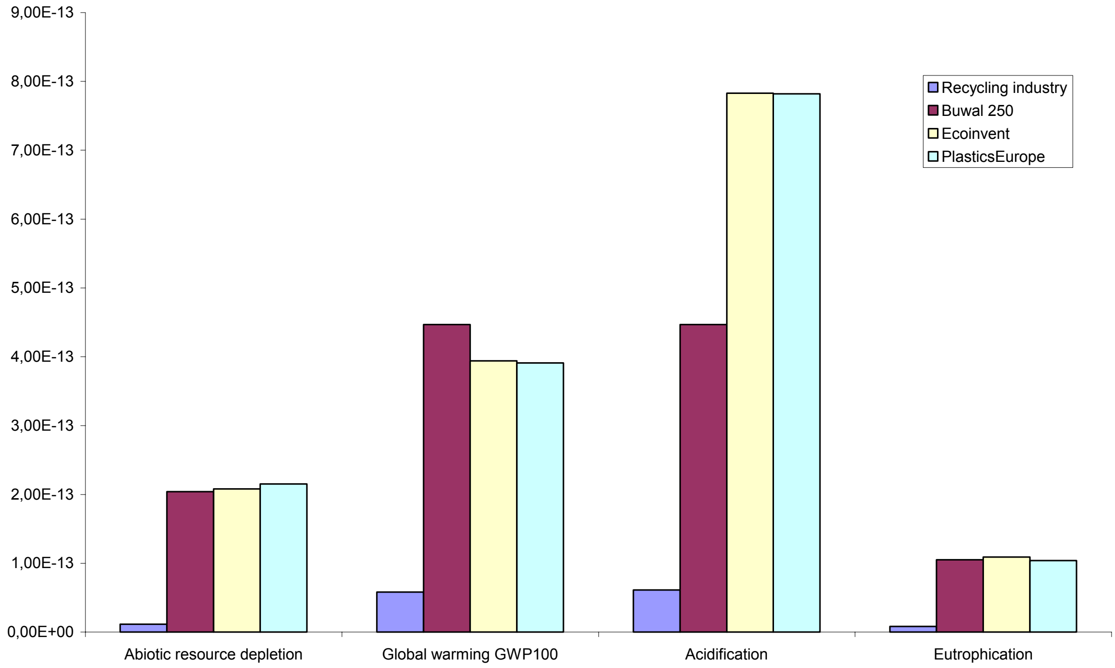

Figure 3: Eco-profile of 1 kg of recycled HDPE vs. virgin HDPE

Discussion and conclusions

There are noteworthy similarities between the eco-profiles using data from HDPE recycling firms. When comparing these results to those from the 1990s, we can appreciate how recycling processes have been optimised, especially in terms of electricity consumption.

The difference between the eco-profiles of recycled and virgin plastic is also considerable. These results come to support the development of new recycled products for a sustainable development.

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References

[1] Tukker A. Comparing feedstock recycling of plastics waste to mechanical recycling methods. TNO, Holland, 2002.

[2] White P.R., Franke, M., Hindle, P. Integrated solid waste management. A life cycle inventory. Ed: Blackie Academic & Professional, ISBN 0-7514-0046-7, 1995.

[3] Deurloo T. Assessment of environmental impact of plastic recycling in P&G packaging. Technical report of Procter&Gamble, 1990.

[4] Perugini F., Mastellone M.L., Arena U. A Life Cycle Assessment of Mechanical and Feedstock Recycling Options for Management of Plastic Packaging Wastes, Environmental Progress, Vol. 24, n.2, pp 137-154, 2005.

[5] Arena U., Mastellone M.L., Perugini F. Life Cycle Assessment of a Plastic Packaging Recycling System, International Journal of Life Cycle Assessment 8 (2), 92-98, 2003.

[6] Habersatter K., Fecker I., Dall'aqua S., Fawer M., Falscheer F., Förster R., Maifeller C., Ménard M., Reusser L., Som C., Stahel U., Zimmermann P. Life cycle inventories for packagings, BUWAL (SAEFL, Swiss Agency for the Environment), Environmental series n.250 (Buwal 250), 1998.

[7] Hischier R. Life cycle inventories of packaging & graphical papers, Part II. Plastics. Ecoinvent report n.11, 2004.

[8] Boustead I. Eco-profiles of the European Plastic Industry. HDPE Extrusion. A report for PlasticsEurope (APME), 2005.

[9] Guinée J. B., Gorreé M., Heijungs R., Huppes G., Kleijn R., de Koning A., van Oers L., Weneger A., Suh S., Udo de Haes H. A., de Bruijn H., van Duin R., Huijbregts M. Life Cycle Assessment: An operational guide to the ISO standards. Ministry of Housing, Spacial Planning and Environment, The Netherlands, 2001.