ENVIRONMENTAL EVALUATION OF GLYCOLYSIS AND HYDROLYSIS OF PET WASTE USING LIFE CYCLE ASSESSMENT

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Abstract

The concern about alternative plastic end-of-life management processes as well as the decrease of environmental impacts is increasing in the last few years. Two different feedstock recycling processes (glycolysis and hydrolysis) for the recovery of PET are compared in this paper from an environmental point of view using the LCA methodology. A cradle-to-gate approach and Eco-Indicator 99 has been used to assess environmental impacts. Avoided impacts from the production of BHET in glycolysis and TPA in hydrolysis have been considered. Electricity in both end-of-life processes is the main responsible of impacts for most categories. This is due to that laboratory data such as energy consumption of the equipment has been used in the analysis. In addition, ethylene glycol and hydrochloric acid in glycolysis and hydrolysis respectively, have relevant impacts for respiratory effects on humans caused by organic substances category. Glycolysis presents a better environmental profile than hydrolysis. However, results of glycolysis and hydrolysis environmental impacts are quite similar.

Keywords: *Feedstock recycling, Plastic, environmental impact, LCA, End-of-life*

1. Introduction

The production and consumption of plastic products has been increasing around 9% since 1950 [1], being the demand from European converters 45 million tonnes in 2009, with 8% corresponding to PET. The packaging sector is the largest application for plastics, with a market share of 40.1% [2]. Although plastic end-of-life management improves yearly, 11.2 million tonnes of domestic post-consumer plastic waste were disposed at landfill in 2009 [2]. Hard coloured, multilayer or highly contaminated PET is included in this waste landfilled, since their mechanical recycling doesn't allow getting a good-quality secondary raw material. Therefore, feedstock recycling processes, like glycolysis and hydrolysis, have been studied in PROQUIPOL project in order to give an added value to this PET packaging waste, obtaining bis (hydroxyethyl) terephtalate (BHET) and Purified Terephthalate Acid (TPA) respectively. Environmental impacts of both processes have been compared using Life Cycle Analysis (LCA) methodology. These LCA results are included in this paper.

2. Materials and Methods

The environmental assessment of the two end-of-life options was made through LCA using a cradle-to-gate approach. Environmental impacts were assessed according to the Eco-Indicator 99 v 2.1 methodology in Individualist (I) perspective.

The goal and scope of the LCA was to assess and compare main environmental impacts of two feedstock recycling processes, hydrolysis and glycolysis, for PET packaging waste.

The functional unit of the study is to feedstock recycle 100g of PET waste.

The origin of the PET waste used both for hydrolysis and glycolysis was the domestic packaging waste stream from Spain. This study does not include impacts associated to the generation of the PET waste.

Sub-processes considered in glycolysis were shredding, glycolysis, extraction-filtration, crystallization-filtration and drying. For hydrolysis, shredding, hydrolysis, filtration, precipitation-filtration and drying were the sub-processes included.

Compilation of primary data for glycolysis was gathered from CARTIF and for hydrolysis from GAIKER laboratories. In addition, Ecoinvent data base was used as secondary data.

Since monomer and acid were formed from both feedstock recycling processes, avoided impacts were included in the analysis as a bonus for both end-of-life options. BHET and TPA industrial manufacturing were the processes avoided for glycolysis and hydrolysis, respectively.

3. Results and Discussion

Results of the LCA for glycolysis and hydrolysis of PET waste were first analysed separately and subsequently, compared one to another.

Figure 1 shows the relative contribution to environmental impacts for each input on the glycolysis of the PET life cycle.

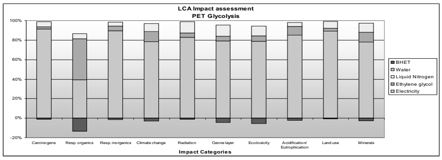

Fig.1 Environmental impacts of the **glycolysis** of PET waste.

Electricity is the process which causes the majority of the impacts in most of the categories and its contribution is similar to all of them except for respiratory effects on humans caused by organic substances category (from now on respiratory organics). These impacts are due to emissions generated in the combustion of coal and lignite used during electricity production. In respiratory organics category, main impacts are caused by the electricity and the Ethylene glycol (EG) which generates non-methane volatile organic compounds, ethene and methane emissions from Ethylene production.

The input which influences in the second place environmental impacts of glycolysis is the EG for respiratory organics and inorganics, climate change, acidification/eutrophication and use of minerals categories. Whereas for carcinogenic, radiation, ozone layer, ecotoxicity and land use categories it is liquid nitrogen (N_2) and specifically, due to electricity required for its manufacturing.

Negative values show avoided impacts from the monomer of BHET obtained in the glycolysis of the PET. For respiratory organics, avoided impacts of BHET represent 18% of the total for this impact category.

Figure 2 shows, for each input on the hydrolysis of the PET life cycle, the relative contribution to environmental impacts.

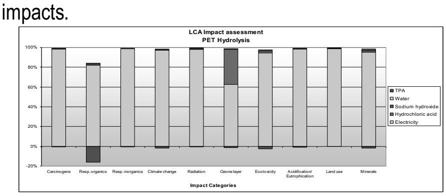

Fig.2 Environmental impacts of the **hydrolysis** of PET waste.

Electricity is again the main responsible of the impacts for all impact categories. Ozone layer is the sole impact category which is influenced by other process significantly which is caused by the Hydrochloric acid production process.

For all impact categories, Sodium Hydroxyle has an impact of less than 1,5% of the total.

Avoided impacts are shown in Figure 2 as negative figures. For respiratory organics, avoided impacts represent 23% out of the total and are due to TPA production from Paraxilene.

Finally, both feedstock recycling processes were compared in order to analysed which present higher environmental impacts.

Figure 3 shows the comparison of environmental impacts among glycolysis and hydrolysis.

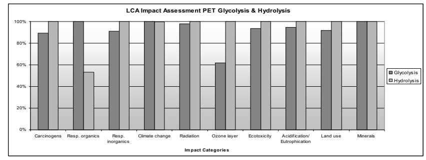

Fig.2 Environmental impacts of the **hydrolysis** of PET waste.

Hydrolysis of PET waste has greater impact than glycolysis for most impact categories, although these differences are no too large.

In order to facilitate comprehension of results, impact categories have being aggregated. In carcinogenic, respiratory of organic and inorganics, radiation, ecotoxicity, acidification/eutrophication and land use categories, hydrolysis present slightly higher impacts than glycolysis. In ozone layer category differences are higher due to Hydrochloric acid production whereas in respiratory organics, differences are caused by EG production. In climate change and minerals, impacts among glycolysis and hydrolysis are similar though for each of them, have different sources.

4. Conclusions

Glycolysis presents lower environmental impacts than hydrolysis of PET packaging waste. However it should be highlighted that these differences are not relevant for many impact categories.

The majority of the impact in all categories is caused by electricity consumption of equipment used since both glycolysis and hydrolysis processes have been carried out at laboratory scale. Energy consumption of lab equipment is much higher than industrial machinery. This fact has been identified and it is actually being studied.

On the other hand, the solvent used for glycolysis (EG) and the Hydrochloric acid for hydrolysis have around 20% of the total impact in respiratory organics category. Nevertheless, it should be considered that EG impact can be recovered by evaporation and reusing in further glycolysis processes.

Next steps in Proquipol project will be scaling feedstock recycling process throughout pilot trials. Then, environmental impacts closer to industrial conditions are expected.

References

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[2] PlasticsEurope "Plastics – the Facts 2010. An analysis of European plastics production, demand and recovery for 2009"

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