Towards closed-loop recycling of multilayer and coloured PET plastic waste

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Flow of plastics

Virgin feedstock

Production

Use phase

Open-loop recycling

Process losses

Closed-loop mechanical recycling

Collected for recycling

Chemical recycling

10%

4%

14%

14%

32%

14%

40%

14%

Incineration

Landfill

Leakage

Ellen McArthur Foundation, 2021. The New Plastics Economy: Rethinking the future of plastics, 2013. URL https://emf.thirdlight.com/link/cmy2sfpast1d-bid6vx
Why can’t we close the loop?

• Plastics are complex materials!

Additives

Colorants

Multilayers

Non-Intentionally added substances

- Limited functionality
- Lower physiochemical properties
- Potential leaching of substances
- Incompatibility issues
- Formation of odorous components
- Degradation of embedded substances

Pretreatment of plastics!
PET trays

- 70-80% used for food and 20-30% for non-food products
- Multilayers
- Various colors (blue, green, black etc.)
- Sticky labels (paper or plastic)
- Recovery and purity of monomers
- Mainly landfilled and incinerated
Delamination of PET plastic waste

• Alkaline hydrolysis of PET in an aqueous media as a promising solution to recycling problems

\[
\text{Ethylene glycol (EG)} \\
\begin{array}{c}
\text{C} \\
\text{C} \\
\text{O} \\
\text{O} \\
\text{O} \\
\text{CH}_2\text{CH}_2\text{O} \\
n \\
\text{NaOH} \\
\text{H}_2\text{O}, \text{CH}_3\text{CH}_2\text{OH}
\end{array}
\xrightarrow{} \\
\begin{array}{c}
\text{C} \\
\text{C} \\
\text{O} \\
\text{O} \\
\text{ONa} \\
\text{O} \\
\text{Na}^+ \text{n} \\text{HOCH}_2\text{CH}_2\text{OH}
\end{array}
\]

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\]

• Identification of main relevant conditions based on 3 factors: NaOH w%, EtOH/H\text{H}_2\text{O} v% and T
Delamination of PET plastic waste

- Characterization of degradation products (GC, NMR, UV-VIS)
- Testing optimized hydrolysis conditions on the ‘real’ PET samples

- PET conversion $\propto T$
- Higher EtOH v% results in higher PET conversion
- There is limit on the NaOH w%
Delamination of PET plastic waste

- Particle size conversion %
- Conversion % of monolayer > multilayer
- Higher thickness and crystallinity, lower PET conversion
Delamination of PET plastic waste

- Hydrolysis under mild conditions
- No catalyst
- Removal of colorants
- Recovery of polyolefins
- Pure PET monomers
Life cycle assessment

Delamination of PET plastic waste via selective depolymerization

- Increasing the solid/liquid (S/L) ratio
- Avoiding excess water addition during monomer purification

Lower energy consumption during purification

Lower carbon emissions
Conclusions

I. Recycling of PET trays is limited
II. Alkaline hydrolysis is a promising route
III. Hydrolysis yield of multilayer PET trays should be increased
IV. Thickness and crystallinity play an important role on the hydrolysis rate
V. S/L ratio and monomer purification have effect on the LCA
THANK YOU FOR YOUR ATTENTION