PhD Open Days

Natural-based solvents for closed-loop physical recycling of plastics

PhD in Chemical Engineering

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The plastic waste problem

Global plastic production is expected to surpass **500 Mt** in the coming years [1].

Polyolefins comprise over **40%** of the global plastic consumption.
Less than **15%** of all end-of-life **polyolefins** are recycled.
These are commonly found in **multilayer films**, containing other polymers.

Common recycling method – **mechanical recycling** – faces strong **drawbacks**:

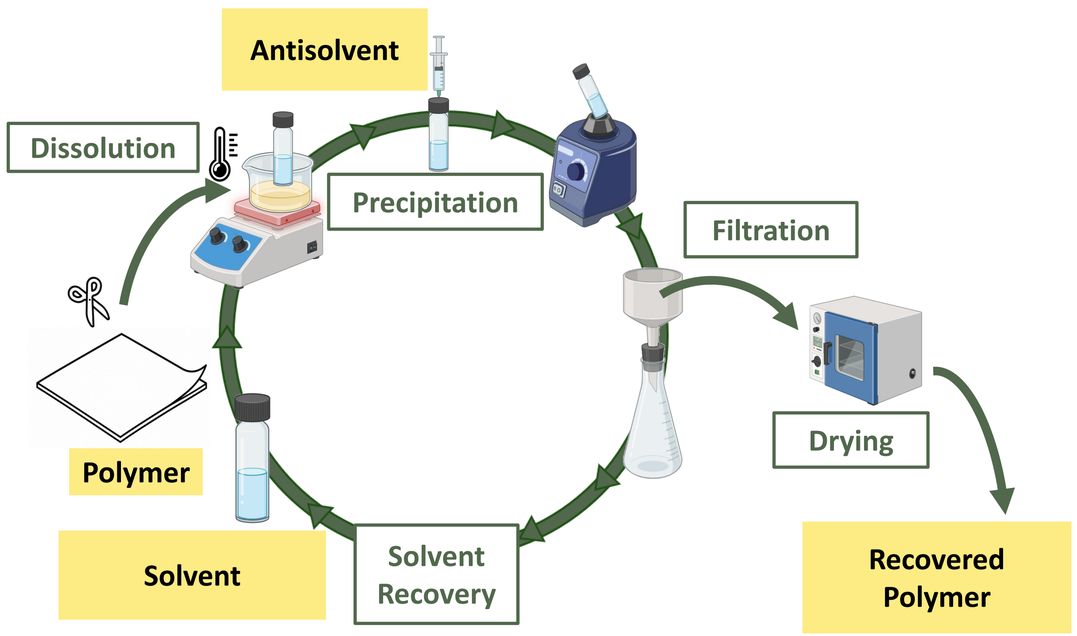
- Fails to handle mixed plastics;
- Is unable to remove additives and contaminants;
- Leads to downcycling of even pure single polymer materials.

Dissolution-precipitation recycling is a promising solution for recycling polyolefins:

- In can separate multipolymer materials;
- It can remove additives and contaminants;
- The material is recovered with good quality.

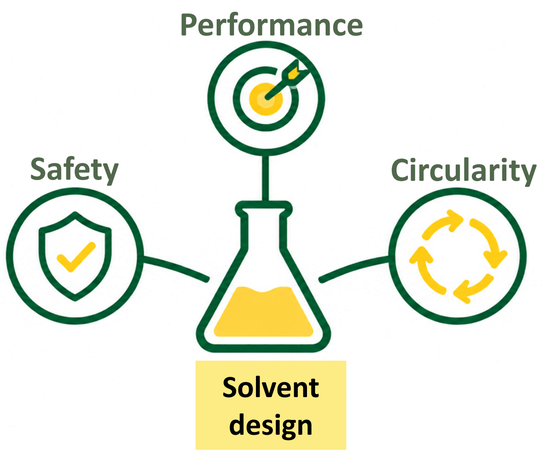
OBJECTIVE:
Replace conventional solvents with a natural and sustainable alternative, while ensuring process circularity.

Dissolution-Precipitation



Solvents in Dissolution-Precipitation

Solvent selection is key when developing dissolution-precipitation processes.[2]



In particular, it impacts:

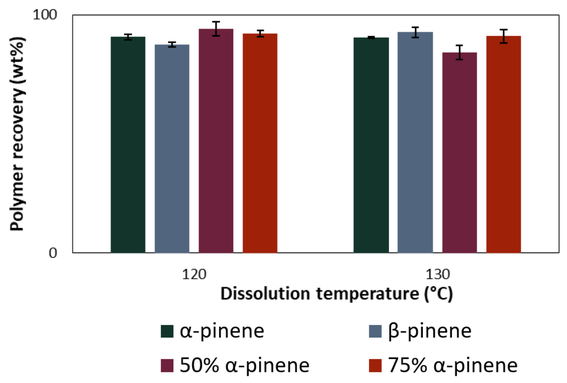
- **Selectivity;**
- Operating **conditions**;
- **Precipitation** methodology
- Quantitative polymer **recovery;**
- Solvent **recyclability;**
- **Quality** of the recovered materials;
- **Sustainability** and economic viability of the process.

Moving towards green solvents

Based on **COSMO-RS** predictions, a list of **natural-occurring terpenes** was selected as prospective polyolefin solvents.
α-pinene yielded the best results for HDPE dissolution-precipitation.[3]

α-pinene was concluded to be a **good solvent** also **for PP and LDPE**.

The combined use of α- and β-pinene would **eliminate the need for their separation,** as these are found in nature together.



Variations in solvent composition did not impact polymer recovery nor phase behavior significantly.

Recyclate characterization

The recyclates obtained from dissolution-precipitation experiments were analyzed regarding:

- Chemical and structural integrity (FTIR)
- Thermal properties (DSC)
- Solvent presence and thermal degradation behavior (TGA).

All samples **were recovered with high quality:** there were no solvent residues and all main properties were maintained equal to the pristine materials.

Next steps: recycling of multipolymer materials

Careful tuning of the solvents and process conditions can enable the efficient recycling of multilayer films and other multipolymer materials, such as:

- multilayer films containing polyamides;
- multilayer films containing polyesters;
- blended textiles.

References: [1] Plastics Europe, The Circular Economy for Plastics – A European Analysis 2024, 2024. [2] S. C. Aparício, J. V. M. Resende, B. D. Ribeiro, I. M. Marrucho, ChemSusChem 2025, e202500018. [3] S. C. Aparício, P. M. Castro, B. D. Ribeiro, I. M. Marrucho, Green Chem. 2024, 26, 6799–6811.
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