*Express Polymer Letters Vol.18, No.9 (2024) 881–882*
*Available online at www.expresspolymlett.com*
*https://doi.org/10.3144/expresspolymlett.2024.65*

*Editorial corner – a personal view*

# Advances and challenges in mechanical recycling of thermoplastics

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The recent 'Global Plastics Outlook' of the OECD (https://doi.org/10.1787/de747aef-en) calls for reducing 'plastic leakage', uncontrolled waste disposal in the environment, to near zero by 2060, and for a global plastics recycling rate of 40% by the same year. The present status is shown by a report of Plastics Europe (PE circular economy): 8.7 Mt of polymers (27%) were recycled in 2022 either mechanically or chemically, an increase of ~23% in just 4 years. Over the same period, the landfilled amount was reduced to 7.6 Mt (25%), while the fraction used in energy recovery still increased to 16 Mt. There is a long way to go, and even more so in other parts of the world.

The majority of mechanical post-consumer recycling (PCR) is based on collected packaging materials, limiting the performance range of the resulting products. Next to come is end-of-life vehicle (ELV) recovery, for which the European Commission has defined a target for 2030: Recycled plastics content in cars should be 25% then, of which 25% are to come from closed-loop ELV treatment. There are at least as many challenges as in packaging: While mechanical performance and stabilisation of the polymers is commonly better, there are more and different contaminants to be faced, like metals, rubber and paint residues (https://doi.org/10.1016/j.wasman.2022.10.006).

Contamination and mixing remain critical for mechanical recycling, as they limit applicability. Recyclers need to understand both the composition of the PCR, commonly dominated by polyolefins and the effects of unwanted components. While hard/soft combinations of similar polarity, like polypropylene (PP) with inclusions of linear low density polyethylene (LLDPE), can be acceptable up to ~10 wt% (https://doi.org/10.3390/polym12051171), already much smaller concentrations of polar polymers can be detrimental (https://doi.org/10.3390/polym14020239).

Compatibilisers and modifiers are expensive, making blending with virgin grades at 30–50 wt% PCR content attractive. As in 'normal' polymer design, understanding structure-property relations and the real requirements of applications are necessary for success.

This also explains why 'Design for Recycling' (DfR) has become a critical element in any design process, from pouches to cars. For packaging, DfR guidelines like the ones developed in Austria (FH-campuswien circular-packaging-design-guideline) are helpful, indicating which material combinations are acceptable or even beneficial for recycling. Commonly used combinations are unsuitable, like LLDPE and poly(ethylene terephthalate) (PET) for trays and blisters, but PP can work as a substitute (https://doi.org/10.3390/polym15132966). Barrier layers, either polymeric or inorganic, will, however, remain a necessity in many cases despite their contribution to complexity.

There still is the basic fact that you can only recycle what has been collected (ideally separately) and sorted. Major investments like by the German company PreZero in Denmark (PreZero denmark), with a capacity of 100–130 kilotons per year, are clearly helpful, as are supply agreements like the one between

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Borealis and Tomra (Borealis-Tomra agreement). Sorting is also getting assistance from analytical developments, where infrared-based technologies have become standard, and machine learning (https://doi.org/10.1021/acssuschemeng.1c04281). For motivating consumers towards less littering and more ordered collection, deposit schemes for single-use packaging are recommended. In the Netherlands, this reduced littered plastic bottles by 70–90% – which should also work elsewhere and help the environment (https://doi.org/10.1016/j.marpol.2018.02.009).

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