To sort or not? The impact of the collection scheme on post-consumer plastic waste feedstock quality and its suitability for mechanical and chemical recycling

A. Schmuck[1], J.S. Coene[1], M. Roosen[1], L. Harinck[1], K. M. Van Geem[2], K. Ragaert[3], S. de Meester[1]
[1]Laboratory for Circular Process Engineering (LCPE), Department of Green Chemistry and Technology, Faculty of BioScience Engineering, Ghent University, Graaf Karel de Goedelaan 5, Kortrijk, B-8500 Belgium
[2]Laboratory for Chemical Technology (LCT), Department of Materials, Textiles and Chemical Engineering, Faculty of Engineering & Architecture, Ghent University, Technologiepark 125, Zwijnaarde, B90-52 Belgium
[3]Circular Plastics, Department of Circular Chemical Engineering, Faculty of Science and Engineering, Maastricht University, PO Box 616, 6200 MD, Maastricht, the Netherlands
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Presenting author: alexandra.schmuck@ugent.be

While plastic production is at an all-time high with a reported 400.3 Mt global production in 2022, recycling rates are still lacking behind with an average global recycling rate at approx. 9% (Plastic Europe, 2023). In order to meet circular economy (CE) and sustainability targets such as defined by the European Green Deal, recycling rates have to increase, however, collecting and sorting for more quantity usually comes at the price of lower quality of sorted bales (Picuno et al., 2021), which in literature is known as the “quantity-quality trade-off assumption” (Brouwer et al., 2019). This includes that more heterogeneous feedstock is more difficult to sort into high purity output at material recovery facilities (MRF) which in turn will have an impact on recycling facilities and quality of recyclates derived from mechanical and chemical recycling processes (Brouwer et al., 2018; Kusenberg et al., 2022). Even if waste items are sorted correctly at MRFs, design choices such as multi-layer packaging, will result in significant contamination on polymer and elemental level (Roosen et al., 2020). These quality constraints may have a significant effect on recyclability of plastic waste and might result in the necessity of extensive pre- or post-treatment (Lase et al., 2022; Roosen et al., 2020), which may have an direct impact on economic performance of recycled plastic (Civancik-Uslu et al., 2021; Larrain et al., 2021). While there exist an increasing amount of studies linking feedstock quality to recyclability of plastic waste in light of CE targets, to our knowledge there is no study that directly compares the influence of the collection scheme on the quality and suitability for recycling processes of sorted waste bales from PMD and post-sorted (PoS) waste streams processed at the same MRF.

This study builds upon the methodology outlined in Roosen *et al.* (2020). We included waste streams that appear most promising for the pyrolysis ambitions of the petrochemical industry: plastic films (mono- and multi layered), PE rigid, PP rigid, and mixed plastic (DKR 350). Waste samples were collected from a Dutch medium MRF (70 kt per year) that processes both PMD and PoS collected waste with a reported sorting yield of >92% (personal communication). Waste samples included randomly collected samples and target items. Random samples were taken directly from the conveyor belts in the sorting cabin prior to baling (PE rigids, PP rigids, Mixed plastic). LDPE random samples were collected by MRF employees. Target items were selected to represent common item for each waste polymer stream, and a total of 10 replicates per item were collected. Additionally, special items more likely to be encountered during PoS operation were taken such as toys, textiles, and household plastic items. All samples were placed in plastic bags, labelled and stored in a fridge (5 °C) until further analysis.

The analysis steps included i) quantification of mass fraction of packaging subcomponents and residue fraction through washing, drying and weighing of samples prior and after washing, ii) quantification of polymer composition based on ATR-FTIR and IR microtome, iii) quantification of VOCs of unwashed samples performed on a Pyro-GC-MS, and iv) quantification of elemental composition including CHNSO content (PerkinElmer 2400 Series II CHNSO Elemental Analyzer), metal concentration (ICP-OES Thermo iCap 7200) and halogen concentration (IC Eco Metrohm).

Plastic waste bale qualities were determined following the performance indicators defined by Roosen et al. (2022). A material flow analysis (MFA) (e.g., Kleinhans et al., 2021; I. S. Lase et al., 2022; Roosen et al., 2022) was used to model the flow of material and elements through the sorting facility, and subsequent recycling process lines. By linking the performance indicators to the outcome of the MFA, the suitability of sorted plastic waste bales for mechanical and chemical recycling processes was determined.

Preliminary results include 5% - 13% higher residue content for PoS PE and PP rigid, and mixed plastic fractions, while polymer quality in terms of mono material fraction was on average higher for PMD waste except for PE rigid and LDPE bales. PoS random samples may contain higher metal concentrations than PMD samples, e.g. for aluminium, copper, iron, potassium, sodium, lead, antimony, and vanadium. VOC, elemental, and halogen analysis is ongoing.

We expect to see a qualitative difference between waste samples of the different collection schemes. PoS samples may be more contaminated due to the combined collection of plastic packaging with other household waste in one bin. This difference may have an impact on subsequent recycling operations in terms of quality of derived recycling products, suitability for chemical recycling, and necessity of enhanced recycling processes in terms of pre- and/or post-treatment.

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