Recycled material derived from printed packaging can be decontaminated to an acceptable level for safe use

On-pack decoration defies recyclability

Boosting post-consumer food-grade polypropylene's circularity with a focus on inks, labels and adhesives.

By Professor Edward Kosior and Paul Marshall of Nextek and NextLooPP

One of the biggest challenges to the plastics' circular economy is that a vast proportion of plastic products are still being designed with little thought to optimising their recyclability for a circular economy. The European Commission's Packaging and Packaging Waste Regulation (PPWR) mandates that all packaging be recyclable by 2030, with additional requirements for including recycled content.

Food-contact polypropylene (PP) packaging, which is PP's largest fraction, will be subject to stricter recycling and content requirements as part of the EU's circular economy goals, with recycled content thresholds designed to reduce dependency on virgin plastics while maintaining food safety standards.

Boosting food-grade recycling is key

To boost plastics circularity, particularly for polyolefins and films, food-grade recycling is critical, and this Directive is accelerating the need to find the best solutions to ensure what is produced can be effectively and simply recycled back into high-quality resins.

As it stands, even with ideal collection, sorting and recycling rates (75% collection, 95% sorting, 85% recycling), recovery yields still only reach about 60%. In a circular economy where materials are recovered at the end of one life cycle, we must go beyond our old recycling boundaries to eliminate unintended build-up of package elements that might travel with the plastics during recycling. These include the inks, adhesives, binders and labels as well as the pigments that should be reduced and optimised for recycling to boost rather than hinder the circular economy.

Recent research into inks, labels and adhesives has revealed both opportunities and challenges in achieving high recycled content packaging targets.

Novel testing strategies for contact-sensitive recycled plastics packaging

The European Food Safety Authority's tight threshold requirements to prove the absence of potential harmful substances can't always be easily demonstrated with classical chemical analysis testing due to the very low levels of detection required for substances that might be of concern. This led to a Europe-wide initiative, SafeCycle, whose goal to tackle potential contamination in recycled plastics focuses on materials intended for food-contact and cosmetics packaging.

SafeCycle, which is coordinated by partners such as Fraunhofer IVV, OFI and FH Campus Wien, has been investigating testing methodologies to determine DNA-reactive substances that arose in some recycled plastics and not in others after extrusion and were considered toxicologically significant. These very low level contaminants, which are challenging to detect and characterise with traditional analytical methods, have been found to create a response in a modified Ames test for mutagenicity.

Following their initial findings, SafeCycle dug deeper to identify exactly what was causing the issue by developing a comprehensive testing protocol utilising high-resolution mass spectrometry, liquid chromatography, and bioassays. These methodologies aim to identify and categorise contaminants, thereby helping to develop guidelines for safer recycling processes that prevent these substances from entering recycled materials.

Reaction of inks during recycling

Unprinted polyolefin film that is re-extruded did not cause a problem. However, where packaging was printed, or had labels, glues, binders and inks, the extrusion step triggered

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the release of decomposition products that were identified as mutagenic responsive triggers to the modified Ames test.

Refining findings further it was established that the re-extrusion of nitrocellulose binders was one of the main contributors. As for inks, each colour comes with its own spectrum of challenges with organic yellow being one of the most concerning.

Whilst inks are strictly regulated and fit-for-purpose during their application, meaning nitrocellulose binders would never be used in packaging that requires high-heat exposure such as ovenable packaging, once in the recycling stream, with no control of the input, they will be heated to T >250 °C during extrusion. In these conditions, the inks will degrade, making the recycled material unsuitable for contact-sensitive applications due to safety concerns.

Re-shaping solutions to boost PP circularity

Tackling the big question of ensuring that recycled material derived from printed packaging can be decontaminated to an acceptable level for safe use in food-grade packaging, even after going through the extrusion process, requires deploying state-of-the-art technologies that enable us to overcome the current boundaries. And we are making good progress in this direction. Whilst more work needs to be done to validate our findings, NextLooPP's high-performance decontamination process, which relies on extracting volatile and semi-volatile materials in the melt stage and the solid state and the PPristine food-grade resins, has passed the modified Ames test showing no mutagenic responses.

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Furthermore, Nextek's novel technology, COtooCLEAN, uses supercritical CO_2 process to extract contaminants from polyolefin films to very high rates.

One of NextLooPP's participants, HydroDyn, the innovative cleaning technology company, has developed an advanced approach for removing labels, adhesives, inks and other contaminants from recycled plastics. This process centres on its innovative HydroCleaner and HydroSeparator technologies, which can eliminate up to 99.9% of extrinsic contaminants, including ink from labels.

Inks and coating specialist Siegwerk has been running in-depth studies to investigate the de-inkability of direct-printed PP cups. Adhering to DIN SPEC 91496, the tests resulted in complete ink removal, with ΔE values ranging from 0.5-1.5, well below the acceptable limit of 3.

As Andrey Charkovskiy, senior business partner recycling and polymers at Siegwerk, points out following these trials, by confirming the effective de-inking of PP direct-printed cups under hot caustic washing conditions – a method increasingly adopted in the recycling industry for producing consumer packaging recyclates – this project highlights the necessity for Design for Recycling Guidelines to adapt to newly established and effective industrial practices.

Design for Recycling must align with test findings

It has becoming strikingly clear that to address these more complex circular economy recycling issues, we must continually reassess our guidelines for Design for Recycling, taking these findings into account and re-aligning with latest recycling technologies that overcome these hurdles. This starts with ensuring that all on-pack decorative material is totally removable, everything from adopting labelling systems that detach from the pack through to stable formulations for inks and binders must be proven to be suitable for the subsequent recycling operations at the early stages of packaging design.

Adhesives need to separate from the package and must remain with the label when being recycled. NextLooPP participant Bostik has developed the next-generation range of wash-off label solutions for PP, HDPE and PET.

Another NextLooPP participant, MCC Verstraete's NextCycle IML technology, addresses the IML issue with its NextCycle removable IML solution tailored for rigid polypropylene packaging. This system allows decorated packaging to be recycled with minimal interference. During recycling, the labels are designed to shrink and then separate from the PP containers in the hot washing phase, preserving the integrity of both materials.

As the design requirements of food-grade polypropylene post-consumer packaging recalibrates to comply with EU food safety regulations, particularly Regulation 1616/2022 ('recycled plastic materials and articles intended to come into contact with foods'), the packaging, adhesives, pigments, label and printing industry must shift their thinking and their products to a closed-loop system where plastics such as polypropylene can be reused without compromising safety or functionality.

We have no choice but to address the contamination hurdles and either redesign the packaging with suitable decoration concepts or use innovative technology to overcome them. The NextLooPP project and related projects are focussing on developing commercially viable solutions achieving this.

From left: Marcio Amazonas and Edward Kosior

Following its success in Europe, the NextLooPP project is now being extended overseas as well.

With the launch of NextLooPP Americas, like its European counterpart, the initiative aims to close the loop on post-consumer, food-grade recycled polypropylene (FGrPP) and use science-driven technologies to fast-track production of high-quality FGrPP from local post-consumer packaging for use in food-contact materials throughout the Americas.

To lead the initiative, the team has named Marcio Amazonas as vice president for NextLooPP Americas. Amazonas has experience with managing sustainability strategies and technological innovations in the packaging and waste management industries.

The project is actively seeking participants from across the American polypropylene supply chain.