

Analyze That episode transcript

Turning Waste into Quality: A Smart Screening Approach for Optimizing Plastics Recycling

This transcript has been lightly edited for clarity, readability, and length. The content reflects the original discussion and technical intent of the speakers.

Simon: Hi, Julian. Nice to meet you and welcome everyone else for a new episode of Analyze That. Today we have a very interesting topic for you, which is melt filtration and how it can be used as an efficient screening tool in plastic recycling. So I want to briefly introduce myself. I'm Simon and I'm responsible for applications mostly focused on X-ray diffraction here at Thermo Fisher Scientific.

I also have a little bit of background in X-ray fluorescence spectroscopy, also called XRF, and about different other analytical techniques. And my background is in solid state chemistry. And I hold a PhD from Leipzig University. And I'm with Thermo Fisher for already nine years. And here with me I have another very interesting colleague. Please, Julian, introduce yourself.

Julian: Thank you for this introduction. So my name is Julian Ungerer and I'm application specialist for polymer extrusion and characterization at Thermo Fisher Scientific. For already four years. And I'm a chemical and process engineer with a background and have a PhD in materials science. And my work focuses on extrusion, compounding and mechanical recycling. And with a particular emphasis on translating lab-scale processes into industrial recycling solutions. And before we dive into the technical details of this talk today, it's worth looking at a broader challenge facing the recycling industry and driven by legislation and ambitious recycling targets. Recyclers are expected to process growing volumes of plastic waste. However, many of the additional waste streams entering this market are highly heterogeneous and complex, mostly complex contamination profiles, and for a large proportion of these materials, suitable recycling and purification concepts either do not yet exist or are still under development.

And as a result, recycler needs faster and more efficient ways to evaluate new waste streams and develop appropriate process strategies. And traditionally, our traditional process development can be time consuming and resource intensive, and especially when dealing with large numbers of different materials.

Simon: And this is exactly why we did this study and where it really comes into play, because we wanted to demonstrate how lab scale melt filtration can be combined with

some advanced analytical techniques. For example, rheology or as a surprise, EDX can provide a rapid and cost-efficient screening approach. So, from an analytic perspective, post-consumer plastics are very complex materials because, I mean, they come from various sources.

They can contain various different polymers or any type of material. I mean, if you stay with us, you might learn a little bit more about that, but maybe you, Julian, can explain a little bit why melt filtration is such a crucial step during the extrusion of such materials.

Julian: Because contamination is one of the biggest limiting factors in mechanical recycling and during the extrusion process. Foreign plastics such as metals, glass fibers or mineral fillers, or in the end, melted residues can damage the equipment, can destabilize processing, and finally reduce the product quality and iteration in the lab. Scale environment allows us to remove these contaminants directly from the polymer melt. But the challenge is that every waste stream behaves differently. And that's why a screening in a process or in a lab scale environment becomes so valuable. And it allows us to quickly evaluate which filter configuration fits best before implementing them into industrial production.

Simon: Yeah, this is also very important for circular economy because these recycled plastics are expected to replace a virgin polymer materials in the process at a certain stage. I mean, if you already look into a supermarket, you see that there are a lot of packaging materials which state that they contain 80% recycled plastics or even 100% recycled plastics.

And but these recycled plastics, they have to come from somewhere. So someone has to do the recycling and create a starting material which comply with certain quality regulations. I mean, it also depends on what packaging material you're producing. There are differences between detergents, for example, or food, of course, and there are also different criteria for that. And what we are doing here allows us to get a much better understanding of how the process works and how the processing influences the properties of these materials.

Julian: And one of the central technologies in this work was the combination of principle compounding and filtration. And from our perspective, Simon, why is homogeneous processing so important for analytical characterization?

Simon: There are a few points here which are really important because in the end we are doing science. So for meaningful analytical results, we have to make sure that we have representative and especially homogeneous samples, because even if we get a large batch of recycled, we want to make sure that the sampling we make represents a good average of the whole batch of material we got.

And of course, these recycled materials or this recycling, they have very strongly varying local compositions. But twin-screw extrusion can improve mixing and dispersion, which makes both the material properties and the analytical measurements much more reliable.

Julian: Yeah, exactly. And extrusion also allows us the integration of other additives or stabilizers or other absorbers to improve on one side the process quality and on the other side the quality of the recycled material. And in industrial recycling you need the flexibility. Or this is extremely valuable because recyclers are dealing with continuously changing feedstock qualities.

Simon: And from the analytical side, this also means we can better correlate the process conditions with the material performance and the contamination levels. So we have been talking about melt filtration and stuff. Could you explain how the filtration screening process was performed in practice? I mean, we have a lot of theoretical discussion now. But how did it work in practice?

Julian: Yeah, certainly the experiments were carried out on a large scale, Thermo Scientific Process 16 parallel twin-screw extrusion system equipped with a filtration die, a water bath and a pelletizer, and you're able to quickly replace the filter meshes by pushing them out with a new filter insert to reduce the process downtime to just ten to 30s.

The process started with purging the system without a filter to get stable baseline conditions. Then increasingly smaller mesh sizes were inserted while monitoring the pressure development in the die, and as contaminants accumulated in the filter, the pressure increased and once a critical pressure level is reached, the filter was exchanged and the next configuration was tested, and this allowed us to rapidly identify which mesh sizes were suitable for different waste stream qualities.

Simon: This sounds very, quite interesting also from materials perspective because it could indirectly reflect contamination types and in their concentrations.

Julian: Yeah, exactly. The pressure is the most important indicator during this filtration process, because stable pressure generally means stable process conditions. And while certain pressure increase occurs or fluctuation, this indicates mostly high contamination or in the end, a filter blockage. And one of the most interesting findings here in this work was the very different behavior between the tested ABS and the PP recyclates. And the ABS came from real toolboxes or from used toolboxes. Whereas the PP recyclates, as Simon already mentioned, came from the post-consumer household packaging waste. And from your perspective, Simon, what did the analytical results reveal?

Simon: Already, if you use optical microscope you could already see differences in these materials. For example, the ABS showed comparatively moderate contamination and a relatively stable filtration behavior. While the polypropylene contained significantly more fibrous or heterogeneous contaminations. But I mean, this is also expected because especially the polypropylene is household waste. So it basically could contain anything. And this was really visible in the optical microscopy and we could also correlate this to the pressure curves.

Julian: And this also explains why these different waste stream requires very different filtration strategies. And the one of the key takeaways or key industrial takeaways in this work is there is no universal filtration solution for the recycling, and each filter needs always to be adapted to a specific feedstock characteristics.

Simon: And I mean beyond just the removal of contamination, we also used rheology to analyze the melting behavior and the viscosity of the samples. So why are these measurements actually so important in recycling? Julian, can you explain a little?

Julian: Yeah, sure. Because rheology directly tells us how polymer melt behaves during processing in an extruder or in an industrial process environment. And it helps us evaluating viscosity, elasticity, stability, or in the end, the flow behavior of a processed material. And furthermore, viscosity is closely related to molecular structure, meaning that measurements can reveal changes in polymer architecture caused by degradation, chain splitting, branching, or cross-linking during processing, and in the recycling environment. It is especially important because the polymer may already have undergone degradation during its previous life cycle.

Simon: Yeah. And very interestingly, the viscosity measurements showed that the polymer structure itself was largely unaffected by the filtration process. This was just an interesting finding.

Julian: Yeah, exactly. And this was, in the end, a very positive result because it means the filtration process removed the contaminants without significantly damaged the polymer matrix itself.

Simon: Yeah. But also at the same time, the storage modulus which changed indicated that there were still contaminations which influences the flow behavior of the samples. And this nicely shows how sensitive rheology can be as a quality control tool.

Julian: Simon, your field comes now into play strong here. Why are techniques like XRF and XRD becoming increasingly important in the plastics recycling environment?

Simon: As already mentioned previously, these recycled plastics are far more complex than virgin materials, and they very often contain unknown fillers, additive pigments, metals, mineral contaminations, all kind of different components. And therefore, we need analytical techniques that help us understand what is actually present in the material. And one tool you can use are X-ray based techniques which are very useful here.

And one tool we used is called EDX or energy-dispersive X-ray fluorescence. And this is a tool for elemental analysis. In principle EDX is a technique or X-ray spectroscopy is a technique where you would irradiate a sample with X-rays, and the elements in the sample will emit. So you excite them, and then they will emit characteristic radiation which you can detect afterwards.

And this gives you a fingerprint to identify the elements in the sample and also quantify them. And in a polymer material, the matrix itself is basically carbon and hydrogen

because it's a polymer. But the other materials which are fillers or contaminants, they mostly contain iron, calcium, silicon, titanium. In our case, we also found some barium and some zinc and so. This is a quick way to do an elemental analysis of your recycling streams.

Julian: And yeah, so it tells us which elements are present in the material.

Simon: Yes, exactly. So that's what it basically does. It identifies the elements which compose the sample. But this is not a full picture because even after you identified the composition, you still do not know where these elements are actually located. So because, for example, if you take titanium as an example, titanium could be bound in different materials.

And even if you look at titanium dioxide, which is the most simple compound, there are even two different forms of titanium dioxide, which is called rutile and anatase. And they already have different behaviors in polymers. So it's actually important to distinguish between the two. X-ray diffraction as a technique works on crystalline materials.

So this means a crystalline material is formed by a 3D arrangement of atoms. So this means they form a periodical structure in all three dimensions. And if we know if maybe some of you will remember back your school days or early studies. There is an experiment in physics where you do laser diffraction grating. So you have a grating and a laser.

You shoot at it and behind the grating you will find a minimum maximum pattern, which allows you to do some calculations on the grating. If we now think about our 3D arrangement of atoms, it also forms a crystal lattice because it's periodical, it has distances. So it's a grating. And if we now use a radiation which has an energy or a wavelength close to the distances of this grating, we can do a similar experiment as the one with the laser just using X-rays and atoms.

And the pattern we get from each of the materials, for example quartz or calcite, they will form a very unique pattern which allows us to identify these materials even in a complex mixture, like a recycling stream or different polymers.

Julian: Understand it. Right. So, EDXF tells us what elements are present in the polymer matrix, while XRD tells us how those elements are incorporated in the material.

Simon: Thank you for helping me to make this a little clearer. Yes, exactly. That's what the two techniques are doing. And the combination of the two is very powerful in recycling because you can identify the elements in your recyclate and with XRD that can help you to determine whether these elements are bound in calcite or in quartz. There is also magnetite. There are different forms. And another application which is important is the detection of heavy elements, like for example, lead or other heavy elements, heavy metals, which could be toxic, for example. So it's also very helpful for the analysis of recycling streams.

Julian: And all these are extremely valuable from a processing perspective because it helps us explaining the pressure buildup during filtration, filter lifetime, and even the final material properties.

And as mentioned before, the combination of the EDX and XRD will not only allow us to understand the current material quality, but also supports better sorting strategies for optimization and further feedstock qualification.

Simon: Yeah, and modern recycling increasingly combines process engineering with advanced material analytics.

Julian: And that combination in the future will be essential for producing high-quality recyclables that, in the end, can compete with virgin material in demanding applications. Because of course, we will always need packaging materials and we have infinite resources. So recycling is actually very important.

Simon. And if you had to summarize the key outcome of this work, what would you emphasize?

Simon: I would say that this study clearly demonstrates that using lab scale melt filtration combined with advanced analytics, it's really a highly efficient, highly effective approach for understanding and optimizing recycling processes.

And there are in terms of analytical techniques, for me, the ones which stand out are what we showed today, which is extrusion. We have largely optical microscopy and XRF and XRD, because combining those will give you a very comprehensive picture of contamination and material quality.

Julian: From the processing perspective, the work shows that on the one side lab scale screening using our Process 16 extruder with the filtration die can significantly reduce the development time, material consumption, and scale up risk before you go into industrial implementation.

And in more broadly, this reflects the future direction of plastics recycling, because we really need smarter processing, deeper analytics and more targeted materials upgrading than really simple waste reprocessing. And exactly. And this is ultimately what will enable a truly circular plastics economy.

Simon: Yeah. So thank you for your thoughts, Julian. And thank you for joining us today. And we hope that this discussion highlighted how the combination of all of the techniques mentioned, I know it's a lot that was melt filtration. We talked about extrusion and also advanced material characterization, how it can support the development of really efficient recycling processes.

Julian: And if you would like to learn more about the analytical techniques discussed today, including EDX, XRD, rheology, or about lab scale extrusion and in the end, recycling solutions, please feel free to contact us and thank you for listening and we look forward to continuing the conversation advancing plastics recycling and supporting a more circular economy.

Julian: Thank you.