Odor and Out

Treating Post-Consumer Recyclates to Remove Odors

During extrusion, recycled pellets from post-consumer material principally lose high volatile odor substances. To make them suitable for an even wider range of end products a downstream thermal-physical cleaning process removes the high molecular odor substances.

Recyclates from production and industrial waste are already used as secondary raw materials on a number of production lines. In the post-consumer sector, the recycling of PET bottles has long become established even for food contact grade applications. A key reason for this is the collecting and sorting systems for these materials which work efficiently in many regions. Aside from PET bottles, the potential of the remaining post-consumer wastes has yet to be exploited. This is attributable to factors such as severe fluctuations in the quality of the input material.

Continuous improvements in sorting, washing and mechanical recycling have contributed towards improving the quality of recyclates from post-consumer material. However, substances which cause unpleasant odors cannot be adequately removed within this processing chain and using existing extrusion technology. Thanks to the interplay of the Intarema TVEplus with ReFresher technology it is possible to remove a considerable proportion of these odor substances. While the extruder system primarily takes care of the high volatile, low molecular substances, the ReFresher also removes the low volatile, high molecular odor matter (**Fig. 1**).

Post-consumer problem: For recycled pellets from municipal waste to give off less unpleasant odors they have to undergo a two-stage treatment process (© Erema)

Keep Odors Out in the First Place

A typical problem of plastic from municipal waste is that the packaging absorbs the odor of the food, cosmetics or cleaning agents inside it. The high molecular substances which migrate into the plastic are particularly stubborn odors. Further potential sources of odor cannot or can only partly be removed when sorting and washing. These include wood residues, paper remains (e.g. labels), rubber- and silicone-like contaminants, printing inks and food residues such as oils or fats.

In conventional processes these impurities in the extruder input material can burn easily during extrusion, change chemically as a result and thus create an odor which transfers to the plastic. This can be avoided through the mechanical recycling of post-consumer waste in which degassing and filtration techniques in particular inhibit the development of odors. In Erema's Intarema-TVEplus system the material's dwell time inside the large-scale preconditioning unit of up to one hour already reduces any odor. This is where the input material is heated to the polymer-dependent operating point. Thanks to the large active surface, high volatile, low molecular substances can escape from the material and are already removed by the integrated air flow ("Airflush" technology) prior to extrusion.

Following pretreatment the dry, degassed and warmed through material is dosed into the directly connected extruder. It is precisely in this transitional area between the preconditioning unit

and extruder that Counter Current technology shows how effective it is. Inside the preconditioning unit the rotation of the rotor disc which is equipped with tools forms a rotating spout (donut-shaped fow along the mixer wall) so that the material is circulating the whole time. Unlike conventional systems, this material spout moves in the opposite direction to that of the extruder. As a result, the relative speed of the material in the intake zone increases to such an extent that the screw acts like a sharp cutting edge which now "cuts out" the plastic. This principle is the reverse of conventional technologies in which the material in the cutter/compactor moves in the direction of the extruder. The centrifugal forces released in the process were used for the feeding of the extruder and the treated, warm material was thus pressed into the extruder screw. The inverse tangential configuration of the Counter Current system, on the other hand, ensures that the extruder screw is filled virtually pressure-free with the preheated material. The screw takes exactly as much material as required. The extruder always has the ideal filling level and is never overfilled, making it much easier to regulate.

The second degassing phase, referred to as reverse degassing, takes place inside the extruder, whereby – thanks to a special screw design – any gas inclusions from the melt are sent back to the preconditioning unit where they are removed. This is followed by gentle melting up to filtration. The short length of the screw means that the material is subjected to only minor shear stress. The gentle treatment at a low melt temperature and low shear forces mean that impurities such as cellulose (paper or wood), rubber or silicone do not burn which also prevents further odor development. The contaminant particles remain large enough for the laser filter to remove them (besides foreign polymers such as e.g. PET, PA or in part PP) efficiently before they can form unpleasant odors. In the patented TVEplus zone the melt is subsequently homogenized and brought to the necessary temperature for extrusion degassing to enable any remaining gas inclusions and odor substances to escape from the melt in the final double degassing zone.

At this point, i.e. after extrusion, the odor has been removed to such an extent that the recycled pellets produced from post-consumer materials are already suitable for many applications. Such end products are extrusion products such as primarily construction film, carrier bags, bin liners and pipes or injection molding applications such as covering caps.

Removing Low Volatile and High Molecular Substances

Up to now, however, it has not been possible to adequately eliminate odors created by low volatile, high molecular sub-

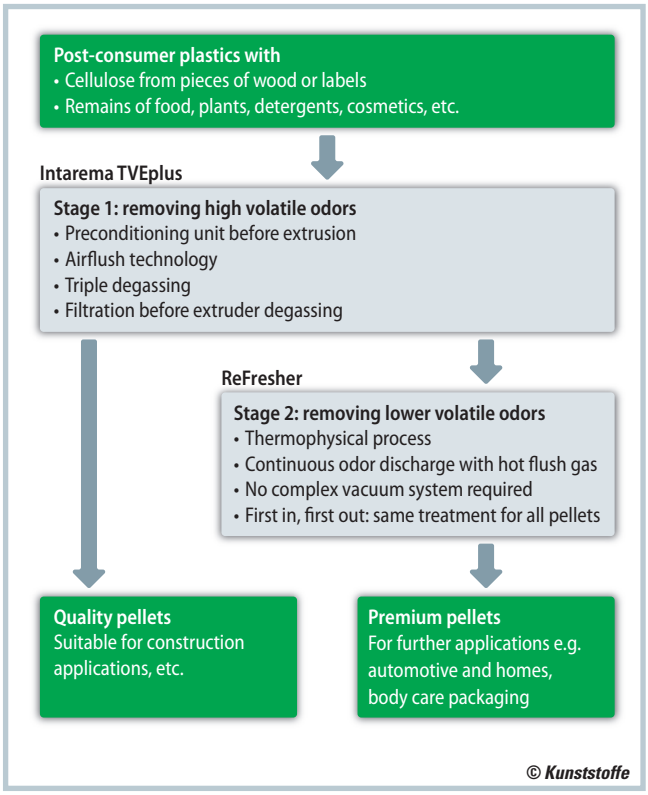

Fig. 1. Process overview: Odor-reduced pellets are created when not only the low molecular but also the low volatile, high molecular substances are removed (source: Erema)

How Odors Are Measured

According to a study [1], humans can distinguish between over one trillion different smells. Volatile Organic Compounds (VOCs) represent a significant group of odor substances. The most common method of analysis is gas chromatography, which determines changes in molecular mass. Due to their low molecular mass, high volatile substances vaporize faster than the low volatile and high molecular substances, which can only be expelled using special techniques. Limonene, which has a slightly citrus smell, often acts as an indicator substance.

The major challenge with odor substances lies in the fact that the odor of VOCs can be sensed by humans even in a concentration which is far below the usual detection threshold of 1 µg/m³ [2]. Revealing analyses, therefore, require the combination of gas chromatography findings and sensory panel analysis. These panels comprise specially trained odor-sensitive people who judge the odors. Sensory panels are put together in different forms due to differences in the perception of odors according to region and culture.

The Author

Clemens Kitzberger is Business Development Manager for Post Consumer Applications at Erema Group GmbH in Ansfelden, Austria:
c.kitzberger@erema-group.com

Service

References & Digital Version

- You can find the list of references and a PDF file of the article at *www.kunststoffe-international.com/3601846*

German Version

- Read the German version of the article in our magazine *Kunststoffe* or at *www.kunststoffe.de*

stances. To either mask such odors or capture the odor-relevant molecules, additives can be added to the extrusion process. This approach, however, contradicts the circular economy ideal. Because when the changed plastic is recycled once again at the end of its product cycle, the recycler is then confronted with additional additives – besides contaminants – which in turn influence the property profiles of the plastic and may release the odor substances previously absorbed when the new processing begins.

Instead, Erema uses a thermophysical process to remove odors. In this process the warm, recycled pellets, which are still hot on the inside, pass from the extruder via a conveyor system into the process hopper in which they are brought to the desired process temperature. The pellets are flushed with air as a purge gas to discharge and remove the odors. The ReFresher uses the principle of "first in, first out". The recyclates as a whole have a narrow dwell time spectrum as a result. After the required process time, the recyclate enters a cooling hopper in which it is brought to filling temperature.

The circular approach was a conscious consideration in the design of the ReFresher. The warmth, for example, which is created in the final pellet cooling is passed back to the process hopper to bring the recyclates to the necessary process temperature. Only a minimum amount of energy from an external source is required. The customer's existing sources of heat can also be used here, such as hot steam from the washing plant. As hardly any moving parts are used inside the ReFresher, availability is high and servicing costs are low.

VOC Test

The Institute of Analytical Chemistry and Food Chemistry at the University of Graz in Austria investigated the relationship between VOCs (Volatile Organic Compounds) determined by gas chromatography and odors sensed by specially trained assessors using volatile and odor-active compounds from recycled plastic samples. Gas chromatography-olfactometry, in which the human nose is used as a selective detector for odor-active compounds, enables the identification of odor-active parts in samples with a complex composition. In this method, the volatile compounds are separated using gas chromatography and the substances which have been separated are smelled and evaluated at the so-called sniffing port by the assessors. A conventional parallel detector is used for identification. Both "traces" are laid over each other to mark the odor-active sections. The compound tests show that a strong sense of odor is possible despite low VOC values measured (**Fig. 2a**). Odors are, therefore, identifiable when no VOCs are measurable, i.e. the odor-causing substances lie under the detection threshold of the detector. Another finding is that low detected VOC values correlate with a lower odor sensitivity of the assessors (**Fig. 2b**).

All in all it is to be noted that the samples have a high proportion of VOCs prior to the extrusion process which is then reduced in the course of processing. The odor of the samples develops as a sum of numerous odor-active individual compounds, some of which have such a high odor potential that they lie under the detectability of the "classic" detectors but can be sensed without difficulty by the human nose.

Gas Chromatography Tests

A series of tests carried out on behalf of Erema by the Fraunhofer Institute for Process Engineering and Packaging IVV examined volatile, organic substances in washed HDPE regrind from shampoo bottles – a typical post-consumer material from the municipal sector. The VOC

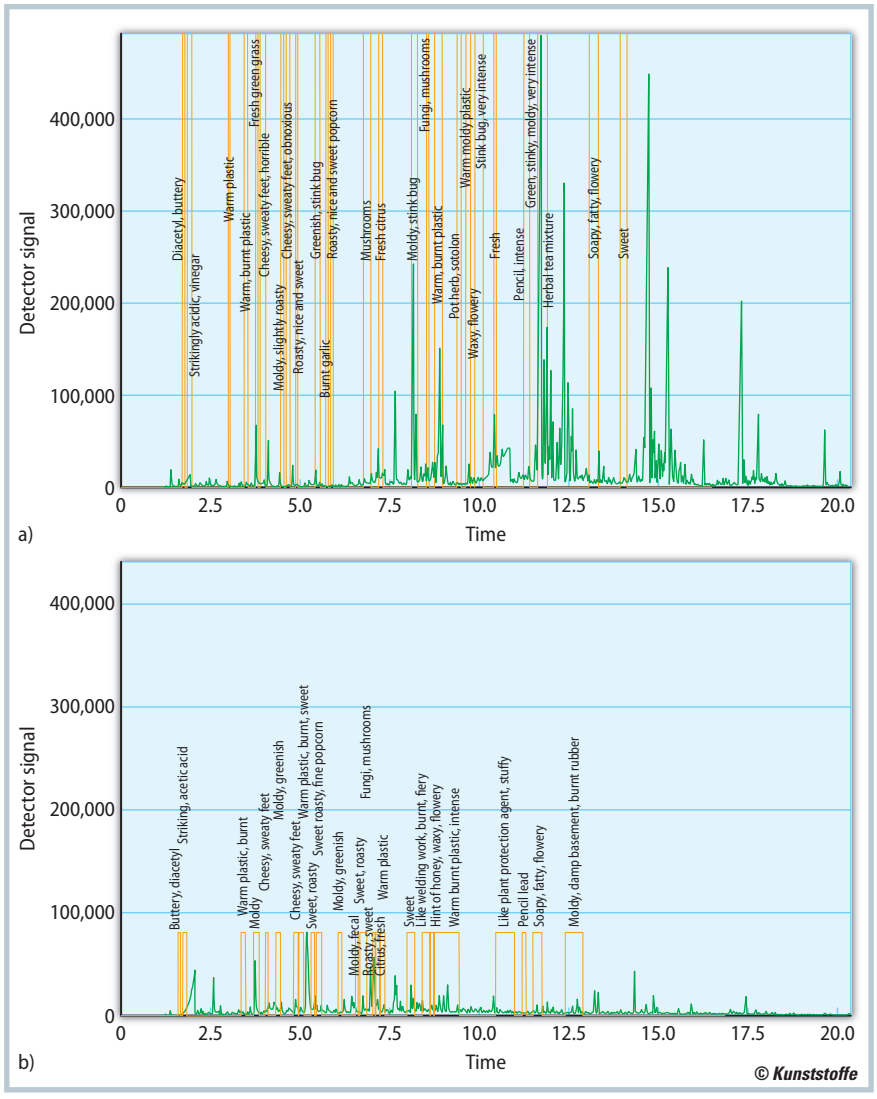

Fig. 2. VOC values (green) and odor perception (orange): a) Assessors can identify odors even if the odor-causing substances (VOCs) are below the detection threshold, i.e. no longer registered by conventional detectors and no peak is visible on the chromatogram; b) lower VOC concentrations correlate with lower odor perception (source: TU Graz)

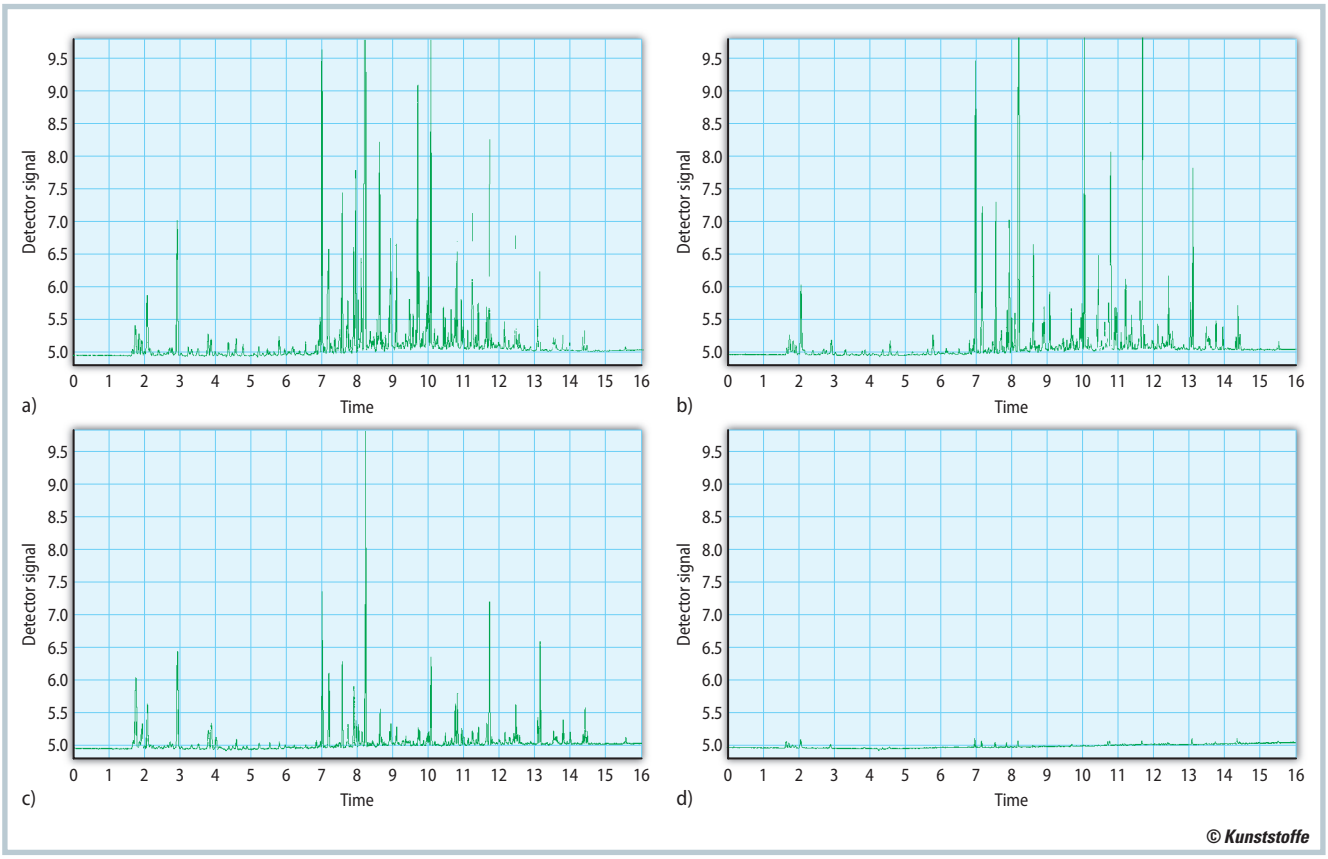

Fig. 3. Gas chromatography VOC analysis to assess odor optimization: The height and width of a peak are an indicator of the amount of the substance. a) Input material before extrusion process, b) after the preconditioning unit (before entering the extruder), c) after the extrusion process with Intarema TVEplus RegrindPro, d) after a further 7 h dwell time in the ReFresher (source: Fraunhofer IVV)

proportion in general (**Fig. 3a**) and the indicator substance limonene in particular were measured in gas chromatography analyses (see **Info box** on p. 48).

The limonene value of the HDPE regrind alone prior to the extrusion process is 73 ppm. After one hour's dwell time inside the preconditioning unit (before entering the extruder) many VOCs have already been considerably reduced (**Fig. 3b**). Following the extrusion process through the Intarema TVEplus RegrindPro the limonene value of the recycled pellets decreases to 20 ppm and the values of the measurable, odor-causing VOCs likewise fall (**Fig. 3c**). After a further seven hours of dwell time inside the ReFresher the limonene value finally amounts to only 0.1 ppm and the other VOC values are also further reduced (**Fig. 3d**).

Conclusion

Small pieces of wood residues, paper remains – from labels, for example – or rubber- and silicone contaminants are potential causes of odor. This is because these impurities can easily burn during extrusion with conventional systems and the odor can subsequently transfer to the plastic. The TVEplus extruder system of the Intarema plant counteracts this development of odor by already vaporizing out high volatile, low molecular substances in the preconditioning unit and discharging them in the course of extrusion. The subsequent cleaning process in the ReFresher removes the odors which stem from low volatile, high molecular substances with air as purge gas (**Fig. 4**). The ReFresher is available in standard versions from 600–4,000 kg/h capacity and with a dwell time of 7–32 hours; the appropriate size depends on the input material and the odor requirements with regard to the end product.

The interplay of the cleaning stages opens up an additional sales market for post-consumer recycled pellets which will be found more and more in automobile interiors or inside homes in the future. ■

Fig. 4. To remove the odors of low volatile, high molecular substances the ReFresher uses the energy of the pellets which have been preheated through extrusion. A hot stream of purge gas ensures continuous odor discharge – depending on the application with a dwell time of between 7 and 32 hours. The dwell time itself is kept the same for all pellets through design measures ("first in, first out") (© Erema)

Masthead Publisher: Carl Hanser Verlag GmbH & Co. KG, Kolbergerstr. 22, 81679 Munich