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Lesson learned

You can‘t do it all alone!

Higher PET recyclate content in end product requires innovative recycling process

From flake to pellet with VACUNITE®

Christoph Wöss, Erema Group, Ansfelden, Austria

EREMA's new bottle-to-bottle process for food-contact-compliant rPET pellets delivers impressive, highly efficient decontamination, compactness and low energy consumption.

In order to be approved for food contact, recycled plastics must meet increasingly stringent quality criteria that lead to more demanding recycling processes. At the same time, the demand for high-quality recyclates is increasing because legal requirements and voluntary commitments of leading brand manufacturers demand a higher use of recyclates in the end products. Although this increases the collection rate, it also leads to poorer quality input materials because the proportion of inhomogeneous components in the material flow also increases. This means that today's recycling plants have to produce better quality output material with poorer quality input material.

With the new VACUNITE® bottle-to-bottle process, a PET recycling system has been developed for the first time that meets these requirements and manages the difficult balancing act between declining quality of the input material and increasingly stringent requirements on the recycled materials.

VACUNITE® PET recycling system

The VACUNITE® process is based on the combination of VACUREMA® technology - which has been proven over the past 20 years and has been further developed especially for this application - together with newly patented vacuum-assisted Solid State Polycondensation (SSP), which was also specially developed by Polymetrix (the manufacturer) for EREMA for this demanding application. The integration of the two technologies (see Fig. 1), in which all thermal process steps take place in a nitrogen and/or vacuum atmosphere, is new, bringing together established technologies to deliver the results demanded by the market.

The process

The starting product is conventional hot washed PET bottle flakes. These are converted into spherical, crystalline pellets with viscosity and purity values corresponding to those of virgin material and which hardly show any yellow colouring. For processing, the flakes are fed via a vacuum conveyor from a big bag or a silo to the first section of the plant, which is based on VACUREMA® technology. Already during the conveying process, the flakes are freed from the very light dust that results from the grinding that takes place during the washing process and various pneumatic processes. Heavy dust and fines do not have to be separated. This is where a significant advantage of VACUREMA® technology comes into play, because thanks to the energy input by mechanical friction, it can handle dust and fine particles much better than other technologies. This process step is particularly suitable for applications in which PET fines, i.e. waste products from the washing plants, are used exclusively as input material because in the production of strapping belts, for example, there is no need for costly and time-consuming dedusting. Previously, this kind of material was used for thermal recycling.

For the bottle-to-bottle application, the flakes are filled in small batches into the application hopper above the entry sluice. This is designed in such a way that it needs to activate once or twice per minute (see Fig 1, item 3). The sluice is necessary to maintain a vacuum in the reactor of <10 mbar. What is new - and a special feature of VACUNITE® technology - is that the sluice and reactor are purged with high-purity nitrogen (99.99 % N_2). In ambient air the oxygen content is about 21%, while at 10 mbar absolute it is only around 200 ppm. Nitrogen purging significantly reduces the residual oxygen content to < 3ppm (0.0003 %) to further reduce the yellow colouration.. At a constant material level of 90 percent inside the reactor, the input material is processed at a vacuum of < 10 mbar. The vacuum lowers the evaporation point of diffused substances such as water and limonene et al (see Fig 2), while surface moisture in the upper part of the reactor evaporates and is extracted within a few seconds. The dwell time in the reactor is between one-and-a-half and two hours, depending on the throughput. The material passes through three process steps. Following the dehumidification described above,

1. Input: hot washed flakes
2. Vacuum Conveyor
3. Vacuum Sluice + N2 infeed
4. Vacuum Reactor with its 3 working tasks + N2 flushing
5. Extruder feeding under vacuum + backward degassing
6. Extruder (plasticising + pressure build-up
7. EREMA Melt filter
8. Melt pump
9. Under water pelletizer, Centrifuge, Inline crystallizing bin
10. Vacuum-System of SSP
11. SSP-Reactor
12. Buffer-Silo
13. Preheater
14. Filter

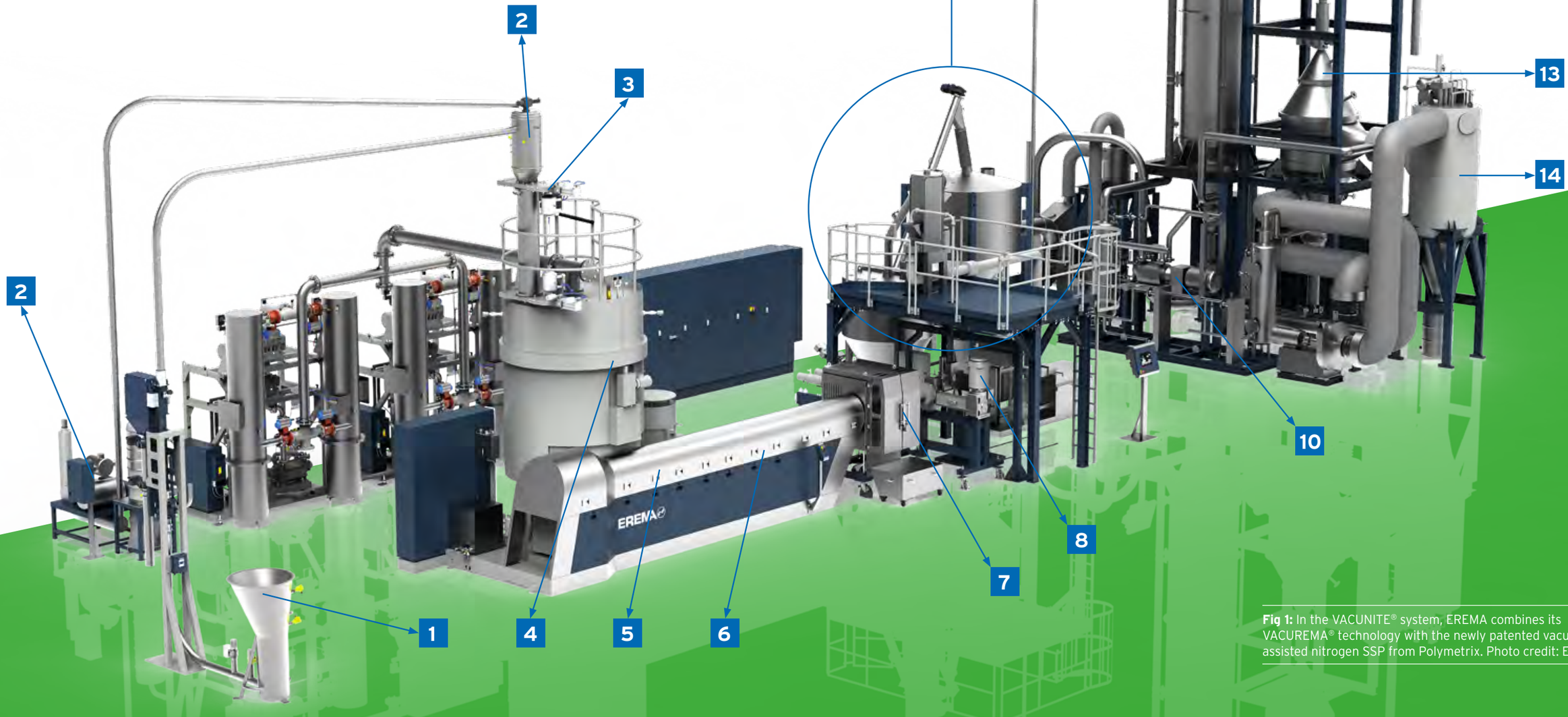


Fig 1: In the VACUNITE® system, EREMA combines its VACUREMA® technology with the newly patented vacuum assisted nitrogen SSP from Polymetrix. Photo credit: EREMA

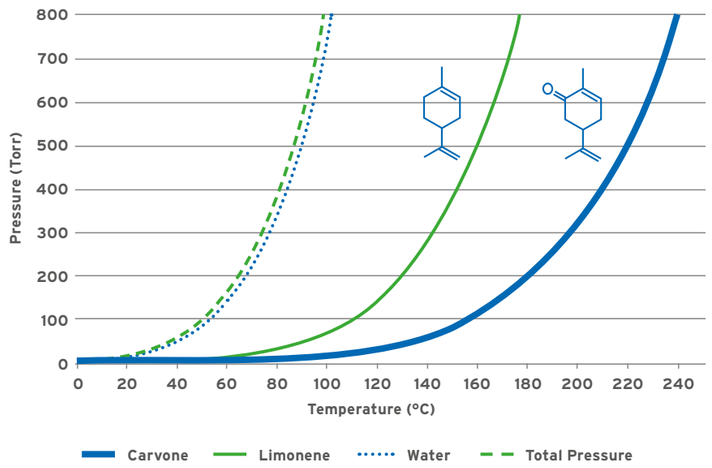


Fig 2: Vapor Pressure-Temperature Diagram for Water, Carvone and Limonene
(Source: Vapor Pressure-Temperature for Water, Carvone and Limonene, graph based on Landrie, 09/2006)

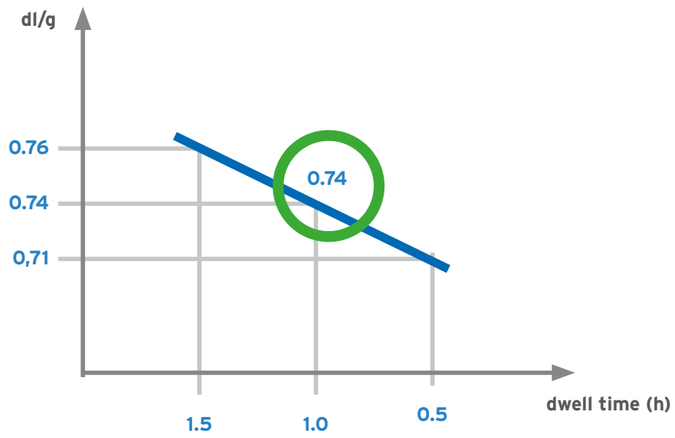


Fig 3: IV stabilization in the first VACUNITE® process section, based on proven VACUREMA® technology from EREMA, source: Erema

it is brought up to process temperature (~ 190°C) within a few minutes using thermal energy generated by the friction of the agitator, and then it is decontaminated. The increased temperature in the reactor causes migrated post-consumer substances and water to diffuse to the surface of the flakes, where they evaporate again due to the reduced partial pressure. This dehumidification stage reduces IV loss.

In addition to decontamination and drying, the bulk density increase inside the reactor is up to 100 % and the flakes are crystallized. This allows the extruder to be fed in a constant flow, which is an essential prerequisite for consistent throughput rates. The material is fed into the extruder under vacuum tangentially in the direction opposite to extrusion. This patented arrangement of reactor and extruder ensures very gentle melting of the PET flakes. Gases given off in the process are extracted backwards via the reactor. Due to the high temperature inside the reactor, the extruder has to introduce less melt energy into the material, so the screw can be up to 40% shorter than in comparable recycling systems. Because of this and because no additional degassing is required in the middle of the extruder, the dwell time of the material in the extruder is considerably shorter. The efficient pre-drying in the reactor and the short length of screw reduce the IV loss of the PET material to a minimum (Fig 3).

Melt filtration

The pressure required for melt filtration is built up in the extruder. This involves an EREMA backflush filter with about 40µm filtration fineness. The advantage of the EREMA filter compared to other filters is the very large active filtration area, which lowers the pressure in the extruder to prevent solid contaminants being forced through the filtration medium. The melt filter operates semi-automatically,

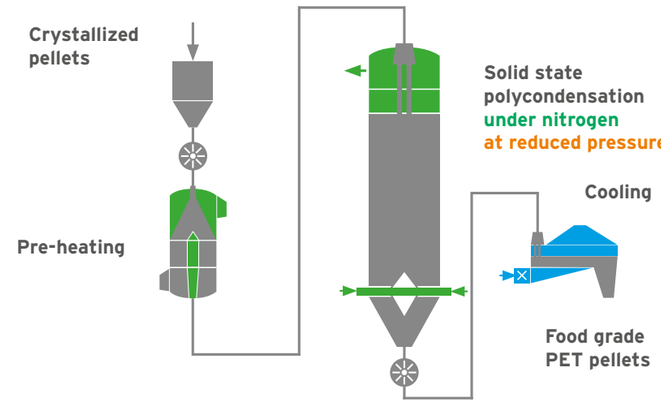


Fig 4: Process flow diagram of the second process stage, the patented nitrogen SSP system, source: Erema

i.e. backflush sequences are triggered depending on the differential pressure and the screen is backflushed with clean material (1 percent material loss). If the backflushing efficiency decreases, the screens must be changed manually, usually once a day.

Inline crystallization (underwater pelletizer)

The filtered PET melt is then cut in hot water and transported a very short distance to the centrifuge, where the pellets are crystallized by latent heat crystallization from the inside to the outside without the need for an external source of energy. The special configuration of this process and the temperature control of the VACUNITE process enables very high crystallization rates (>40%, determined using the density method) without having to install an additional post-crystallization process. This in turn brings advantages for our customers in terms of the number of components and energy efficiency, because overall the VACUNITE® concept requires a good 40% fewer components and thus up to 36% less energy than comparable systems on the market.

Patented vacuum assisted nitrogen solid state polycondensation (SSP)

The food-grade, spherical and crystalline pellets obtained in this way are fed to the nitrogen SSP in a hot state. This patented system was developed exclusively for EREMA by Polymetrix and has the following special features (Fig 4):

The pellets from inline crystallization are blown into a buffer vessel via a pressure transport system. There, a rotary valve separates the ambient atmosphere from the nitrogen environment. In order to counteract discoloration at elevated temperatures, the pellets are then brought

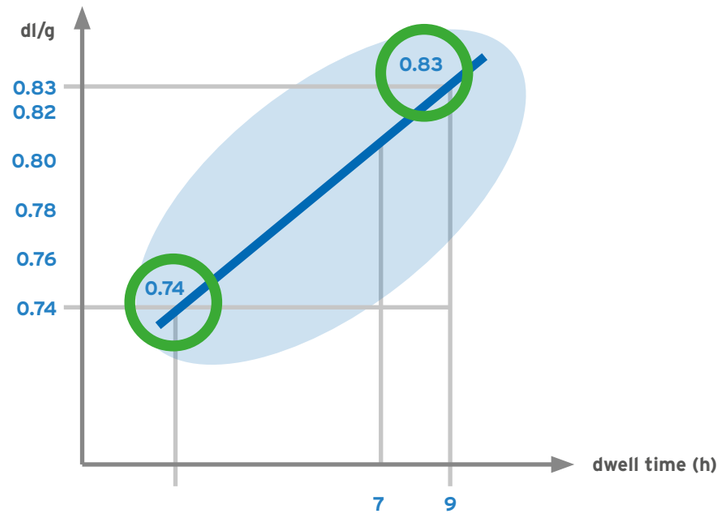


Fig 5: IV increase in patented, vacuum-assisted SSP system, source: Erema

up to process temperature in a preheater with nitrogen and fed into the SSP. There a separation between normal pressure and negative pressure takes place again, so that a vacuum-assisted nitrogen atmosphere can be guaranteed. The vacuum is generated by water ring pumps without additional mechanical boosters, as in this case a moderate vacuum is sufficient due to the dry material. In addition, the SSP is purged with fresh N_2. The combination of vacuum, the right nitrogen flow rate, temperature, dwell time and very narrow dwell time spectrum enables defined process control and results in unique decontamination performance.

The nitrogen is injected into the SSP by means of a contraflow process. On its way to the top, it absorbs contaminants, glycol and water from the pellets, which are the by-products of the IV increasing process. In the subsequent water ring pump system, the nitrogen is purified again so that it can be returned to the upstream process steps. In addition, the viscosity in the SSP is raised again to values suitable for preform production. (Fig 5).

In a final process step, the pellets are finally cooled in a fluidized bed and de-dusted in parallel to increase the transparency of the preforms. The same cooling can also be used for the VACUREMA® BASIC system, i.e. an operating mode without IV increase and without SSP e.g. for sheet or fiber applications is possible.

As an end product, the new VACUNITE® technology produces rPET pellets of unique quality which, in terms of food contact compliance, significantly exceed both the current legal requirements and the even higher requirements of leading brand owners.

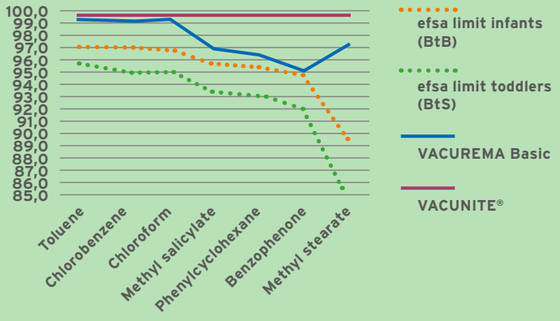
Compact and resource-saving

VACUNITE® is special not only because of the exceptional quality of the output material. The goal during development was also to design a compact and highly standardized modular system, which creates the prerequisite for a very high degree of automation. Depending on the machine type, a floor area of 50 to 60 square metres is sufficient for the SSP section or around 200 square metres for the entire plant (depending on plant size and local conditions, see Fig 6). The height and substructure also have less impact on the dimensions of the plant building compared to other SSP solutions. The energy consumption of VACUNITE® for the entire production process from the flake to the final pellets amounts to a mere 0.35 kWh per kg.

We are sure that with VACUNITE® we have once again succeeded in demonstrating EREMA's role as the innovation leader in PET recycling. Following XTREME Renew (Direct Inline Flake to Preform) in 2017, and world´s first tray-to-tray recycling-system in 2018, we are now offering our bottle-to-bottle customers another innovation - a new technology that sets new standards at all levels, from technical performance to recyclate quality.

Decontamination – Challenge Test

Decontamination performance must be verified in the industry by means of challenge tests. The flakes are artificially contaminated with alternative chemicals, so-called surrogates, and then go through the decontamination process. Then the number of surrogates left is measured. Different values have to be achieved depending on official regulations (efsa, FDA) or specifications of the brand manufacturers (Coca-Cola, Nestlé, Danone, PepsiCo).



Challenge test results VACUREMA® Basic, on which the first VACUNITE® process section is based, source: EREMA, efsa journal 4842, 04/05/2017

VACUNITE® consumption data

Electrical energy: 0.35 kWh/kg | Nitrogen consumption: 75 Nm³/kg

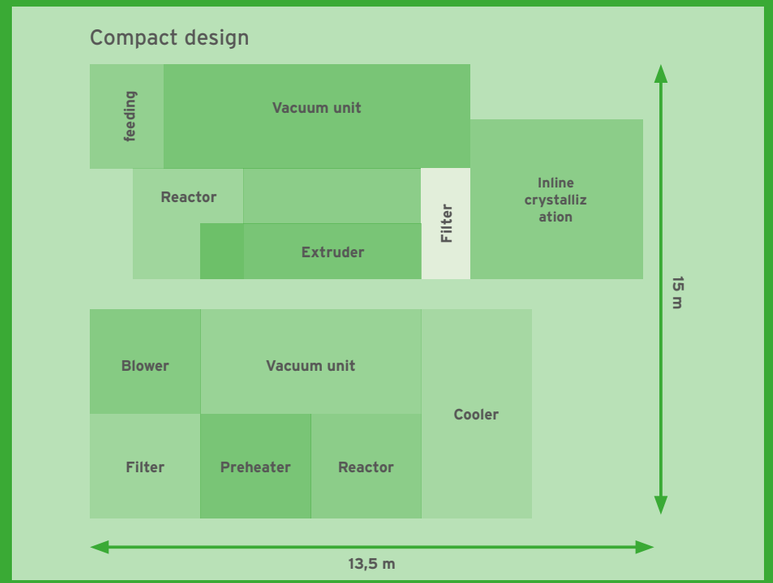


Fig 6: VACUNITE® module configuration and space requirements

Overall, VACUNITE® requires around 40% fewer components than comparable systems and thus up to 36% less energy. This is a major market advantage for EREMA customers.

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You can't do this job alone

Pellets are the initial ingredients for a new product – or how the circular economy means coming together to achieve our goals.

Interview by Barbara and Otto Appel
with Manfred Hackl and Christoph Wöss, Erema Group

RECYCLING CHALLENGES AND STRATEGIES **IN DIALOGUE**

Are recycling technologies the gateway to a better world? The key that opens the complex lock protecting the mountains of waste? During our conversation with Manfred Hackl, CEO and Christoph Wöss, Business Development Manager Application Bottle at EREMA Group GmbH, it becomes clear that the answer to this question is yes. As one piece of the puzzle.

CC: Is there any hope that the plastics industry will solve the world's recycling problems?

Hackl: Certainly not overnight. The issue is still dominated by emotions. However, I can sense that the tide is turning and discussions are becoming more and more rational. Facts are being listened to and debated. And NGOs are also getting involved. Ultimately, we must ask ourselves what alternatives there are to plastic.

Wöss: A change in mindset is underway. As an industry, we recognise that we need to tackle this issue together and cooperate to find joint solutions. We need to focus on the various benefits of plastic and on gaining public acceptance. Recycling plastic must become second nature. As has long been the case for metal and paper. It's all about building trust.

CC: Plastic waste and marine litter are perennial issues. Do you see this as an opportunity or a risk for the industry and your company?

H: Good question! As a manufacturer of plastic recycling machines, we have a business model that is heavily affected by the issues of plastic and packaging waste. At the moment, these terms do not cause any offence. However, if the waste builds up and becomes a problem, people would begin to refer to it as "litter", which, of course, is a term with clearly negative connotations. Our aim is to deal with the waste cleverly and sensibly so that we can avoid producing "litter" by turning recyclable materials into new, reusable raw materials. This means that we see the current challenges as opportunities with great potential. In fact, finding solutions is our mission. I have every confidence that we in the plastics industry can get a handle on these issues.

CC: Do you see yourself as a lone warrior in your value chain?

W: Far from it. At the start of our conversation, Mr Hackl explained how the situation has changed and the industry is now engaging in rational discussions. Something else has changed as well. A few years ago, each industrial sector focused solely on their own areas of expertise; everyone did their job but kept themselves to themselves. There was little interaction between the various parts of the value chain, even between neighbouring industries. Today, people are more open. They show interest in nearby processes, acquire knowledge for their own sectors, share insights into their work and actively participate in discussions.

CC: What exactly does this mean for plastic recycling?

H: The best way to answer this question is to look at the extrusion process. Effective sorting and washing have a positive impact on extrusion and the quality of the recyclate. Ensuring that quality remains consistent over a long period of time requires ongoing dialogue and coordination between the individual processes.

CC: The PET industry has been cooperating like this for a long time. The sector has been able to optimise its work by considering the effects of upstream and downstream processes. For example, lightweighting has become a reality and the industry has reduced its overall energy consumption and its CO_2 emissions. Despite this, there is still work to be done in the PET industry.

H: Yes, PET is an exception. Everywhere you go, there are people working in line with PETnology's motto of "connecting comPETence". The PET industry has

always been the trailblazer. It all began around 20 years ago when plant manufacturers began working more closely with converters and recyclers. This helped pave the way towards today's PET bottles being relatively easy to recycle. As a result, closed-loop systems have become a reality. The situation is much more difficult in the area of polyolefin. Significantly more players are involved here, meaning that the challenges as well as the potential are much greater.

CC: Let's talk about networking. These days, the technology sector is not the only area interested in this field.

W: This is an unbelievably positive sign and creates hope. As machinery manufacturers, we work closely with used plastic, but have relatively little contact with consumers. Instead, it is brands that shape opinions on the market.

CC: Are brands on the right track with their initiatives against marine litter?

H: Every initiative helps to draw attention to the problem. However, it remains to be seen whether all the initiatives are worthwhile and capable of fighting the root cause of marine litter. What's important is that there are enough initiatives to bring people together. It is crucial to raise awareness on a community level.

W: Industries from across the supply chain are following in the footsteps of the brands by launching various initiatives around the world to encourage the development of collection systems and to help avoid plastic waste from "littering" our planet. It is crucial that collecting plastic becomes a standard global practice. And, of course, it has to be made clear that collected waste must not be dumped into our oceans and rivers. Whenever waste is collected, it has to be sorted. This needs to be stepped up a gear as well.

CC: We've already spoken about consumer confidence. A lot of plastic is collected, e.g. in Germany. Consumers here should be confident that they have done their duty and that their waste will be recycled effectively. Having said that, people are still unsure as to what actually happens to their waste.

H: When consumers think about recycling, they generally picture the mechanical recycling process. For them, combustion is not a form of recycling. However, before materials are actually reused, the issue of economic efficiency needs to be taken into account. Sorting companies are paid in terms of the weight of the input material and not the quality of the output material. Waste incineration plants do not like accepting mixed waste, i.e. residual

and plastic waste, because the plastic has a high heating value and fewer tonnes of residual waste can be processed as a result. In the Netherlands, there is now a large waste management company that operates a sorting and incineration plant in parallel. This is a highly efficient way of processing residual waste. The proportion of waste to be combusted is reduced by sorting for and mechanically recycling materials like plastic and beverage cartons. Here, it all boils down to the quality of the separated waste and not the quantity. I believe that this is the approach we need to pursue.

W: The sorting process holds a lot of potential. The more accurately waste is sorted and the more likely it is to be of one type, the better the quality of the recyclate.

CC: How is digitalisation affecting your industry and is it making recycling more efficient?

H: Digitalisation is helping the various links in the value chain to work together more effectively. This is making systems more stable. It is an essential part of manufacturing recyclate to a reproducible quality. In my opinion, this is an important factor in ensuring that recyclate is recognised and used as a secondary raw material on a wide scale. We need to reach the same level as the raw materials industry by producing materials of identical quality over a long period of time.

W: This is an ongoing challenge, as the input material is becoming increasingly heterogeneous.

CC: From our conversation, I could conclude that the benefits of plastic packaging can be pitted against the issue of waste disposal. It is clear that this problem cannot be solved by the recycling chain alone. The situation is far more complex than that and could be compared to a mosaic in which more and more participants are acting as stones.

H: That's a good image. Pieces of the mosaic are cropping up around the world and it's time for us to make it bigger and more capable of bearing the load.

CC: Thank you for sharing your thoughts with us.

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