Plastic Waste into Custom-Made Polyols

Solvolysis Using Different Solvents in Practice

By means of high-performance processes, chemical recycling converts plastic waste into high-grade material for new plastic products. Moreover, freedom of design results by selecting a suitable process and the matching waste material. Hereby, the right combination permits customized polyols to be created for the desired application area.

Not only can multifunctional recycling plants split polyurethane by means of different processes; they are also able to recycle other plastics (© Rampf)

Old mattresses, insulating material, furniture, and steering wheels – this raw material, which Rampf Eco Solutions GmbH & Co. KG, Pirmasens, Germany, processes, is not particularly appealing. The company has specialized on the recycling of polyurethane (PU) and polyethylene terephthalate (PET) waste material. For this, Rampf makes use of the solvolysis process in two of the largest multifunctional plants in Europe. Hereby, solvents are used to split the polymers – the urethane group in the case of PU, for example. The processes differ in the splitting medium applied. Water is used for the hydrolysis process, and acid for acidolysis. Depending on the process, this results in various polyols with different properties. Consequently, the most suitable polyols for the required application area can be created precisely by selecting the corresponding process.

The polyols produced in this way are then returned to the customer's production facility either by Rampf Eco Solutions or another PU system company. Due to the renewed cross-linking, the materials reobtain their initial properties plus high quality. In this way, a recirculatory system is created, with combined economic and ecologic advantages.

For solvolysis, Rampf frequently relies on the glycolysis and acidolysis processes. With glycolysis, the urethane group is split by means of transesterification, mostly with bivalent alcohols (glycols, **Fig. 1**). The process can be used for practically all polyurethanes, although the hydroxyl value (OH value, which indicates the number of hydroxyl groups in a substance) is increased during the reaction. It even exceeds that of the initial polyol, which leads to a higher hardness of the end product. Therefore, polyols obtained with the glycolysis process are mainly used for the production of hard foams, hard integral foams, and durable integral foams.

In contrast, the acidolysis process splits the urethane group with acids or acid anhydride (**Fig. 2**). Compared with glycolysis, the acidolysis process is more complex and more expensive. Because it does not increase the OH value, the acidolysis process is used mainly to obtain polyols for the production of rigid foams, rigid integral skin foams and semi-rigid integral skin foams.

Neither process involves downcycling – instead they are self-supporting upcycling processes with a high added value. For example, by adding recycling polyols, the compressive strength of insulating foams, the chemical resistance of casting compounds, or the compatibility of polyurethane systems can be improved. Consequently, the polyols can be used for the production of numerous end products, e.g. mattresses, seating furniture, automobile and motorcycle seats, fitness and recreation products, as well as insulating materials.

Specially Customized Polyols

Other polymers are also suitable for chemical recycling. For example, way back in 1999 Rampf Eco Solutions developed a process for chemical recycling of PET together with the Deutsche Gesellschaft für Kreislaufwirtschaft und Rohstoffe (German Society for Circular Economy and Raw Materials) in Cologne, Germany. The resulting polyols are mainly suited for the production of hard foams. High mechanical strength and improved flame retardance are the properties which are influenced decisively by these aromatic polyester polyols.

Also polyesters such as polylactide (PLA, polylactic acid), polycarbonate (PC) and polyhydroxyalkanoate (PHA) are used as raw material for producing recycled polyols. Chemical recycling of PC produces aromatic polyester polyols with rigid and very strong bisphenol A structural elements, making them highly suitable for mechanical reinforcement. The compressive strength of polyisocyanurate foams (PIR) could be improved significantly by adding PC polyols. In contrast, polyols made of bio-based PLA are purely aliphatic and very flexible. By adding these polyols, soft segments can be integrated in PU, and the embrittlement tendency of very strong hard foams and casting compounds reduced (**Table 1**).

Hence, functioning chemical recycling processes are available. But compared with mechanical recycling, their application is limited, although they are a good supplement for existing recycling systems – particularly for plastic waste that is difficult to recycle. For example, recycling of bulky waste still represents a great challenge. More than 60 % of the estimated 19 million t of furniture, mattresses, upholstery, textiles, and plastic garden furniture that are thrown away in European countries every year, finish up in landfills.

Therefore, to improve the logistics as well as the disposal and reuse of bulky waste, the recently completed Urbanrec project (**Fig. 3**) was initialized. Companies and organizations in seven countries participated, including national institutions in Belgium, Poland, Spain, and Turkey. Aim was the development and implementation of an ecologically effective and integral disposal system for bulky waste, in order to promote waste pre- »

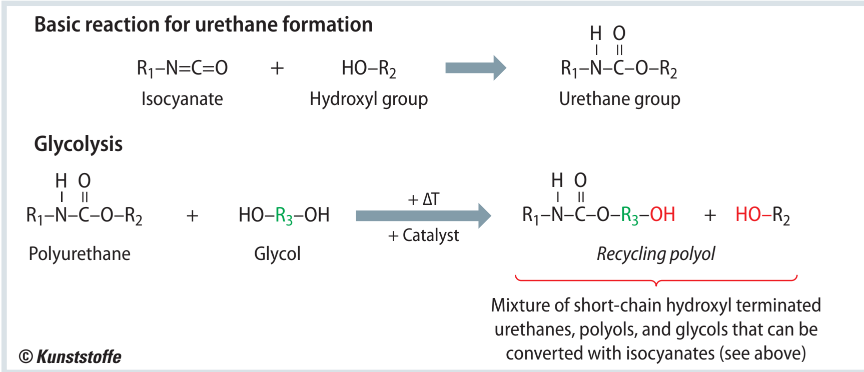

Fig. 1. Reaction equations for production and glycolysis of polyurethane (source: Rampf)

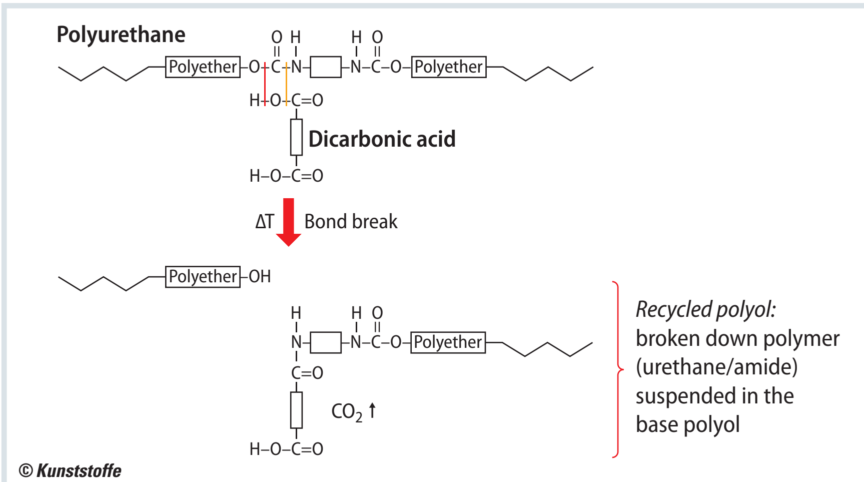

Fig. 2. Acidolysis of polyurethane: hereby, the urethane group is split by the addition of an acid (source: Rampf)

	OH value [mg(KOH)/g]	Viscosity [mPa·s]	Acid value [mg(KOH)/g]	Functionality
Recypole: ether and ester polyols from PU	35–550	2500–9500	1–2	2.0–3.7
Petol: ester polyols from PET or PSA	235–405	300–4000	<3	2.0–3.0
Polyols from renewable raw materials (e.g. rapeseed oil)	250–360	20–350	<2	2.0–2.5

Table 1. Performance data of Rampf's alternative polyols, divided according to source materials (source: Rampf)

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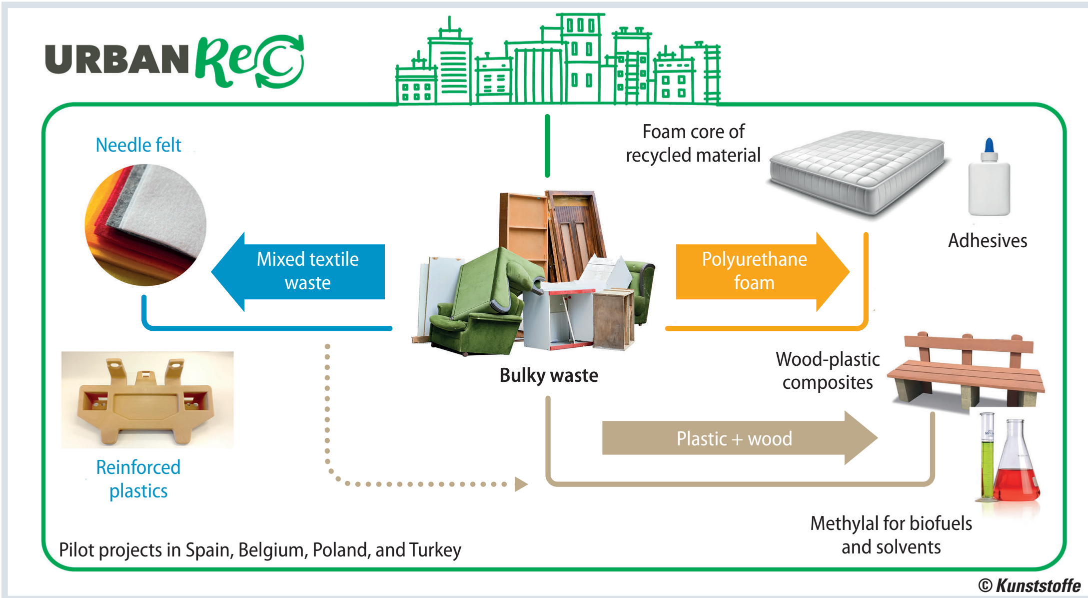


Fig. 3. The Urbanrec project involved the recycling of bulky waste such as mattresses and furniture (source: Urbanrec)

vention as well as recycling, combined with improved logistics.

Chemical Recycling in Practice

Within this project, and together with partner companies and institutions, Rampf Eco Solutions had the task of developing chemical solutions for obtaining high-grade recycled polyols from plastic waste such as mattresses and upholstery. The aim was to reduce the amount of waste delivered to landfills and incineration plants. In addition, new products based on the recycled raw materials were developed during the project, such as adhesives, foams, and insulating materials. Hereby, the polyols involved were produced with the glycolysis and the acidolysis processes.

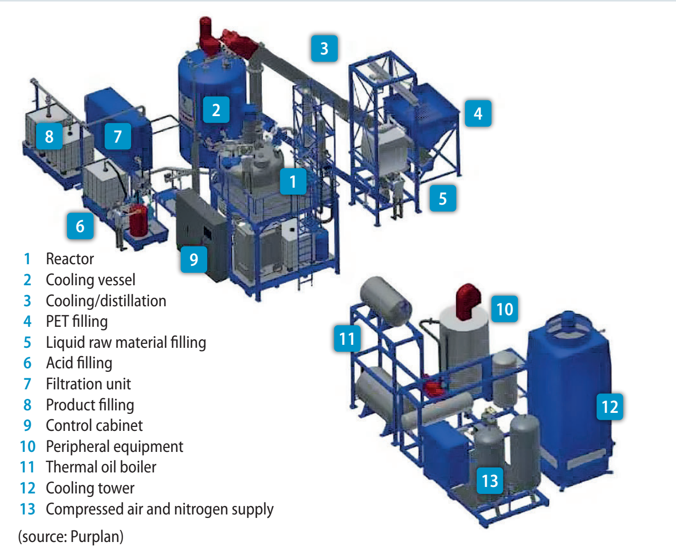
The glycolysis polyols were used to produce insulating foams with a content of up to 50% recycling polyol. Acidolysis polyols were used in the top layers of viscoelastic mattresses (12% recycling content) and for PU hot-melt adhesives (up to 50%). Hereby, it became clear that separation of the PU foam qualities – i.e. ether or ester foams based on methylene diphenylisocyanate (MDI) or toluene diisocyanate (TDI) – was necessary to ensure high-quality polyols. Separation was done by means of near infrared spectroscopy.

Solvolysis as an Alternative

Basically, solvolysis is very suitable for obtaining chemical raw materials from PU and PET. Depending on the plastic waste and the required properties of the end product, the glycolysis or the acidolysis process is suitable. Gradually, chemical recycling is evolving into an alternative for mechanical recycling. Increasing prices for petrochemical products, tighter environmental regulations, and changing sustainability mindsets of consumers make it attractive. Moreover, projects such as Urbanrec illustrate the potentials of chemical recycling in practice. ■

Company-Owned Recycling Plant

An own recycling plant could pay off for producers with large amounts of residual materials. Rampf Eco Solutions has developed such multifunction plants. They enable manufacturers to produce customized polyols, e.g. from PU, PET, PSA (phthalic anhydride), and polyesters such as PLA and PHB (polyhydroxybutyric acid). Apart from Germany, such plants have also been installed in Russia, the United Arab Emirates, and France, amongst others. Plant size is matched to customer needs. The most popular versions have reactor volumes of 5, 10 or 20 m^3. The average production quantity lies between 2000 and 4000 t/a. Depending on the type of PU, operation of an own plant already pays with a residual material quantity of 500 t/a.



1 Reactor
2 Cooling vessel
3 Cooling/distillation
4 PET filling
5 Liquid raw material filling
6 Acid filling
7 Filtration unit
8 Product filling
9 Control cabinet
10 Peripheral equipment
11 Thermal oil boiler
12 Cooling tower
13 Compressed air and nitrogen supply

(source: Purplan)