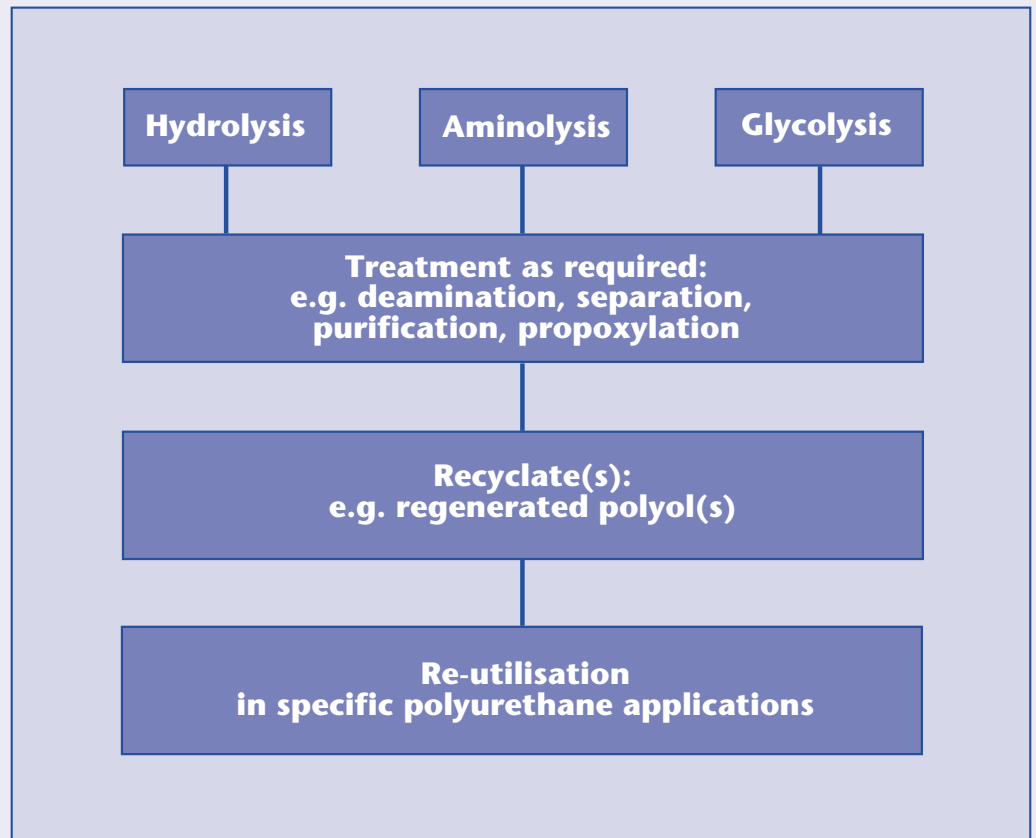


Fact Sheet

RECYCLING AND RECOVERING POLYURETHANES

Chemolysis

Chemolysis is true depolymerisation applicable to the recycling of polyurethanes and other polyaddition materials as well as to condensation polymers such as polyesters (e.g. PET) and polyamides (e.g. nylon). In this type of treatment, the molecules are broken down into smaller building blocks, which may then be reassembled into polymers suitable for use in quality



applications similar to those for which the original components were employed. Because it delivers high-grade products that largely retain their original properties and functionality, chemolysis offers an attractive alternative to mechanical recycling and the recovery of petrochemical feedstocks or energy.

OVERVIEW

For chemolysis of polyurethanes, it is preferable to process feedstock of known composition in order to obtain consistent and predictable regenerated products. Water (hydrolysis), glycols (glycolysis) and amines (aminolysis) typically serve as reagents to break the urethane bonds. The resulting liquid can be used as such, or the individual components separated. In some cases, new chemicals may result,

so a product registration/notification process could become mandatory before undertaking full-scale production.

Several options exist for further reprocessing. These may involve purification and chemical processing before use in polyurethane applications.

TECHNOLOGIES

Hydrolysis

Hydrolysis is a process whereby the PU foam is reacted with water under pressure at elevated temperature. Hydrolysis produces the original polyether polyols together with diamines, which are the hydrolysis products of the original diisocyanates. The various

components are then separated in order to permit their reprocessing and reuse. A number of companies have concentrated their efforts on the development of hydrolysis processes up to pilot plant scale.

Aminolysis

Aminolysis means the PU foam is reacted with amines such as dibutylamine, ethanolamine, lactam, or lactam

adduct under pressure at elevated temperatures. Aminolysis is still at the research stage.

Glycolysis

Glycolysis means the PU foam is reacted with diols at elevated temperature (200°C) with cleavage of covalent bonds. The high molecular weight, cross-linked, solid polyurethanes are broken down to lower molecular weight, liquid products.

Single-phase glycolysis has been optimised by ISOPA members and independent researchers (e.g. catalyst selection, post-treatment for minimisation of the aromatic amine content).

Split-phase glycolysis has been developed up to pilot scale for MDI flexible foams. The glycolysis product separates into two phases :

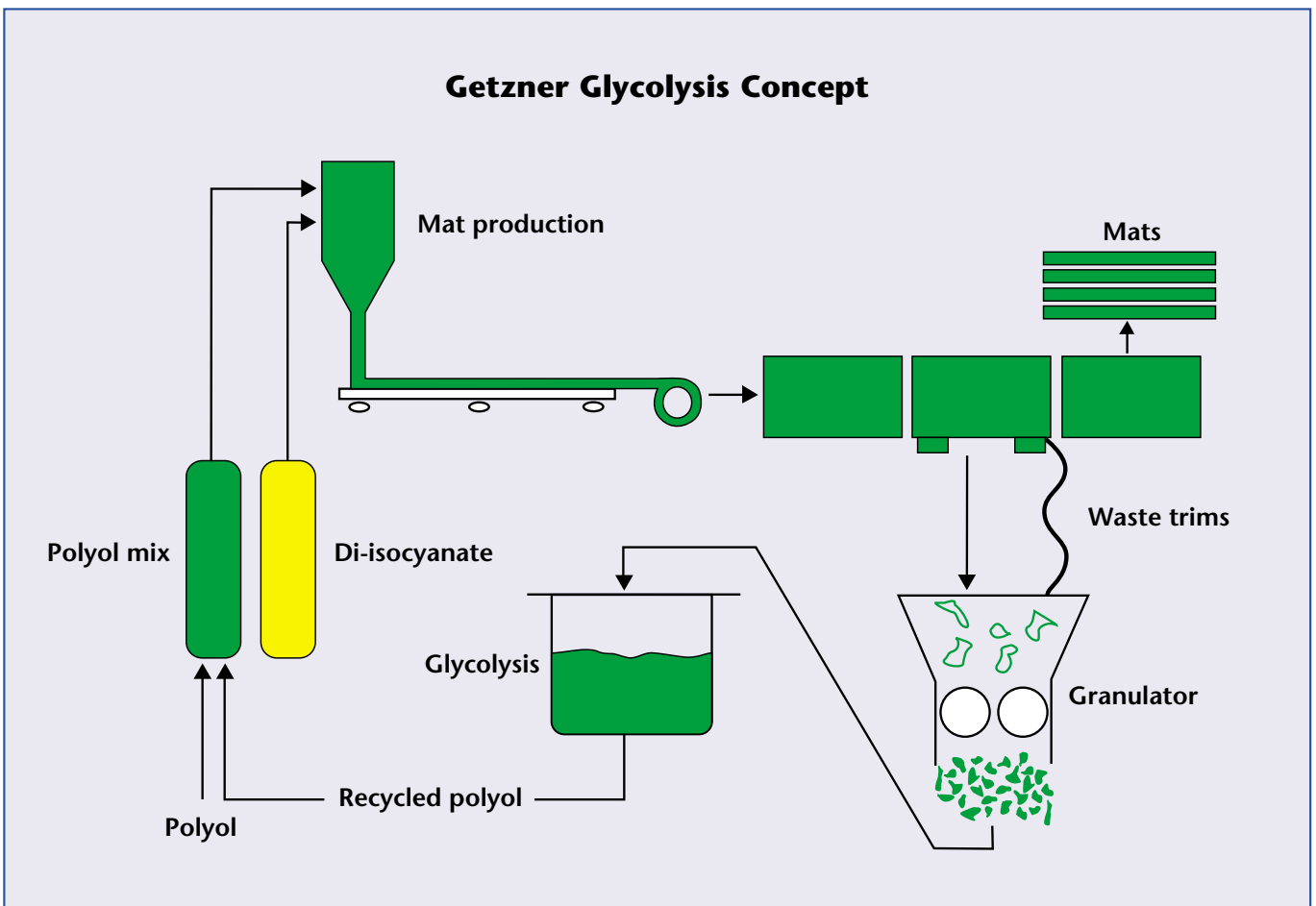
- the top layer is a flexible foam polyol which after purification can be used alone to make the same flexible foam again
- the bottom layer, after post treatment with propylene oxide, can be converted into a high quality rigid foam polyol.

GLYCOLYSIS OPERATIONS BY POLYURETHANE PROCESSORS IN EUROPE

Various polyurethane processors around Europe are evaluating glycolysis technologies either on a pilot or a commercial scale and the today technology allows to regenerate safe polyols. Glycolysis is more appropriate

for recycling production waste than post consumer waste and several companies are operating it as indicated here below :

LOCATION	POLYURETHANE FEEDSTOCK	APPLICATION
Austria	Elastomeric foams/Instrument panels (IP)	Elastomeric foams/IP components
France	Rigid foam	Rigid foam
Germany	RIM	RIM/Integral skin foam
Germany	Shoe soles	Shoe soles
Italy	Shoe soles	Rigid foam
Italy	Shoe soles	Shoe soles
England	Flexible slabstock	Flexible and rigid foam



By courtesy of Getzner Werkstoffe - Austria

CONCLUSIONS

Several types of chemolysis processes have been developed for different foam types. Single phase glycolysis is currently applied industrially. In case of flexible foams, it yields polyols which can replace up to 90% of the virgin polyols in semi-rigid foams, thus bringing the recycled content of "old" foam in the "new" foam to 30%. Similar recycled contents have been reported for rigid foams. Other options in development offer the potential to further enhance recycled content in polyurethanes without compromising product properties.

Since chemolysis or the processing of polyurethane materials by means of chemical reactions can lead to

substances and preparations which may be governed by EU (Directives 67/548/EEC, 88/379/EEC and subsequent amendments) and national legislations, operators and processors who practice chemolysis are advised to consult the relevant regulations prior to putting compounds resulting from chemolysis on the market.

ISOPA member companies continue to explore ways of improving the long-term viability of this technology, with special emphasis on capacity optimisation, the need for regulatory compliance, and health, safety and environmental considerations to provide a sustainable recycling system.

SUGGESTED READING

W.J. Farrissey, Final report to PURRC,
Flexible post-consumer task force, March 23, 1992

E. Grigat : Hydrolyse von Kunststoffabfaellen,
Kunststoffe 68 (1978) 5, p. 281-284

G. Bauer : FAT - Schriftenreihe Nr 86
(Forschungsvereinigung Automobiltechnik e.V.),
Frankfurt 1990

Various authors : Methoden des rohstofflichen
Recyclings, in W. Raßhofer [ed.] : Recycling von
Polyurethan-Kunststoffen, Hüthig Verlag,
Heidelberg 1994 (ISBN 3-929471-08-6), p. 223-276

A. Petrone et al : Progress in the Technologies for
Recycling PU Scraps. UTECH 92, The Hague 1992
Conference papers p. 247-251

M. Modesti, F. Simioni, S.A. Rienzi Recycling of
Microcellular Polyurethane Elastomer Waste,
Polyurethanes World Congress, Nice, 1991. Proceedings
of the SPI/ISOPA World Congress, p. 370-376

G. Bauer, D. Auchter : Chemical Recycling of
PU-Polyols from PU-RRIM and PU-Elastomers
in the Pilot Plant Scale . Davos Recycle '93, p.14/1

D. Hicks, C.B. Hemel, A.C. Kirk, R.J. Stapleton, and
A.R. Thompson : Recycling and recycled content
for PU Foam, Proceedings of the 1995 SPI/PU
Conference, Chicago, September 1995, page 279

C.B. Hemel, "Split-Phase Glycolysis of Polyurethanes
Proceedings of the 1996 ARC Conference in Chicago
on the 7th and 8th November 1996

J. Kerscher, H. Schwager, W. Raßhofer a.R. Pfefferkoon
"Chemical Recycling of an All-Polyurethane Instrument
Panel - Industrial Realisation", UTECH'96, Den Haag,
The Netherlands, Paper 22

B. Naber, V. Neiß, M. Gassan
"New Polyols Made by Glycolysis from PUR and PIR
Rigid Foam Scrap and Their Applications".
Proc. PUR Conf. 1995, SPI Polyurethane Div.,
Sept. 26-29, 1995, Chicago, S. 287-290

B. Naber "Grundlagen der Glykolyse von PUR"
Vortrag, Seminar, Polyurethan in der Fahrzeugtechnik,
Süddeutsches Kunststoffzentrum Würzburg, 21.09.94

B. Naber "Wiederverwendung von Abfällen
der PUR-Schuhsohlenproduktion"
Plaste und Kautschuk 31 (1984) 7, S. 273-275

J. Kerscher, H. Schwager, W. Raßhofer a. R. Pfefferkoon :
"Chemical Recycling of an All-Polyurethane Instrument
Panel - Industrial Realisation", UTECH'96,
Den Haag, The Netherlands, Paper 22

S. Held et al. : "Chemical Recycling Pilot Plant for
Flexible Polyurethanes", Huntsman Polyurethanes,
PU 516-SE, Nov. 2000

Recycling companies are kindly invited to
submit to ISOPA their references in case they are
active in practicing PU recycling and recovery.



ISOPA has produced a brochure and a series of fact sheets on polyurethane recycling options.

The following are now available :

Recycling Polyurethanes (Brochure)

PU in Perspective

Densification/Grinding

Re-use of Particles

Rebonded Flexible Foam

Adhesive Pressing/Particle Bonding

Regrind/Powdering

Compression Moulding

Chemolysis

Feedstock Recovery

Energy Recovery

Energy Recovery from Flexible PU Foams

Recovery of Rigid Polyurethane Foam from Demolition Waste

Options in Practice

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ISOPA - the European Isocyanates Producers' Association - is an affiliated organisation within the European Chemical Industry Council (CEPIC).

Since the original polyurethane material has not been designed for use in articles in contact with food, relevant EU (such as Directives 90/128/EEC) and national legislations need to be consulted, if and when recycled materials are used to manufacture articles and goods for possible direct and indirect food contact.

The information contained in this publication is, to the best of our knowledge, true and accurate, but any recommendation or suggestions which may be made are without guarantee, since the conditions of use and the composition of source materials are beyond our control. Furthermore, nothing contained herein shall be construed as a recommendation to use any product in conflict with existing patents covering any material or its use.

June 2001