BASF
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Ultrason®

High-performance thermoplastics for membranes

Contents

VERSATILE PORTFOLIO FOR MEMBRANES IN VARIOUS INDUSTRIES	04
ULTRASON® E HIGH PURITY PESU POLYMER FOR UF MEMBRANES	05
SUCCESS STORY OF ULTRASON® E 6020 P FOR SUSTAINABLE WATER SUPPLY	13
ULTRASON® PRODUCT PORTFOLIO	14

Versatile portfolio for membranes in various industries

Ultrason® is BASF's brand name for polyarylenesulfones. It encompasses three different product lines: Ultrason® S (polysulfone: PSU), Ultrason® E (polyethersulfone: PESU), and Ultrason® P (polyphenylenesulfone: PPSU). Ultrason® is suitable for the production of membranes in a wide range of applications from ultrafiltration (UF) down to nanofiltration/reverse osmosis (NF/RO) including gas separation and pervaporation membranes.

Advantages of Ultrason® in membrane applications:

- High flux and excellent pore size control
- High-purity material with low content of gels/oligomers
- Excellent chemical resistance (i.e. to water, acids, NaOCl, caustic soda)
- Applicable over a wide pH range (0 - 13)
- Repeated sterilization possible with superheated steam (134 °C), ethylene oxide, γ-radiation
- Complies with FDA and European standards for food contact (repeated use)
- Soluble in solvents commonly used for membrane production
- Easy processing via phase inversion method

Due to its properties, Ultrason® is the most preferred membrane material for:

- Drinking water purification
- Seawater desalination
- Waste water treatment
- Dairy and food filtration
- Wine and beer filtration
- Health care industry
- Produced water treatment in oil/gas industry
- High-purity water production in semi-conductor manufacturing
- Automotive fuel cell and battery humidifiers
- Renewable energy hydrogen electrolysis

Ultrason® E
High purity PESU polymer for UF membranes

The UF water membrane market is dominated by two polymer materials: PESU and polyvinylidene difluoride (PVDF), which account for approximately 90 % of the market.

BASF's PESU, Ultrason® E, shows several advantages compared to PVDF:

- Higher flux and more stringent pore size control, especially in ultrafiltration
- Higher virus removal, in particular for drinking water applications
- Better water quality produced from ultrafiltration pre-treatment for reverse osmosis process
- Higher hydrophilicity than PVDF: less fouling and cleaning frequency
- Less chemicals for cleaning necessary due to inside-out membrane configuration
- Good fiber stability, also at high pH, with adjusted cleaning conditions in waste water treatment

Ultrason® E offers excellent pore size control and up to 80 % porosity in UF hollow fibers

BASF offers PESU materials with different molecular weights. High molecular weight Ultrason® E 6020 P is the most used grade for standard UF applications.

Ultrason® E 7020 P is an ultra-high molecular weight polymer which provides high mechanical strength for special applications and improved chemical resistance towards chlorine. The effects of different molecular weight polymers on UF hollow fiber performances are shown in table 1:

PESU grade	**Ultrason® E 3010**	**Ultrason® E 6020 P**	**Ultrason® E 7020 P**
Mw polymer [g/mol]	52,000	72,000	90,000
Dope viscosity at r.t.p. [m.Pa.s]	19,100	37,300	56,400
OD/ID [mm/mm]	1.22/0.87	1.26/0.93	1.26/0.95
Water permeability [LMH.bar^{-1}]	930	1,630	1,200
Molecular weight cut-off [kDa]	71	56	47
Tensile strength [MPa]	6.1	6.1	6.5

Table 1: Comparison of UF hollow fiber membranes made of different Ultrason® E grades (spinning composition: PESU and PVP (Luvitec® K90), the same dope concentrations and spinning conditions used for all grades)

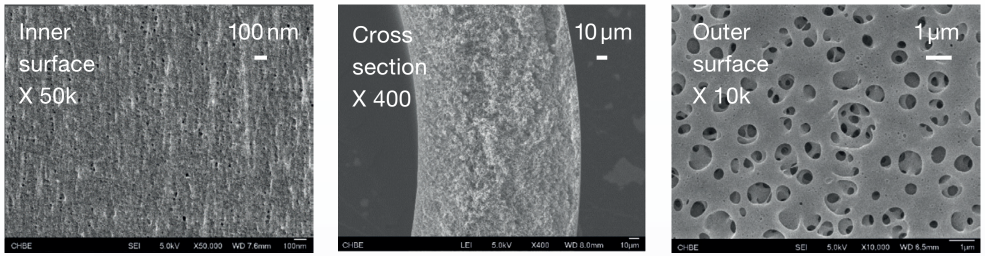
Morphology of UF hollow fibers made of Ultrason® E grades

Both fibers made of Ultrason® E 6020 P and Ultrason® E 7020 P show dense inner surfaces with fully sponge-like structures in the cross-section (no macrovoid formation). With higher molecular weight PESU, i.e. Ultrason® E 7020 P, a higher outer surface porosity can be obtained.

Chlorine resistance of UF hollow fibers made of Ultrason® E grades

Higher molecular weight polymers like Ultrason® E 7020 P and Ultrason® E 6020 P show 50 % less polymer degradation as compared to the lower molecular weight polymer Ultrason® E 3010, when exposed to oxidizing agents, i.e. 2000 ppm NaOCl solution at pH=8 for seven days.

Ultrason® E 6020 P



Ultrason® E 7020 P

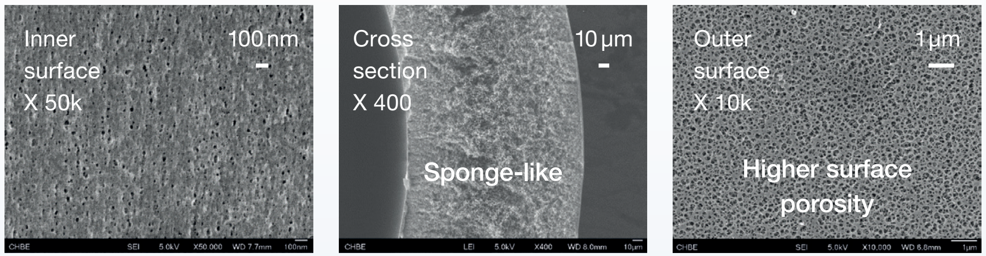


Fig.1: Comparison of hollow fiber morphology made of Ultrason® E 6020 P and Ultrason® E 7020 P

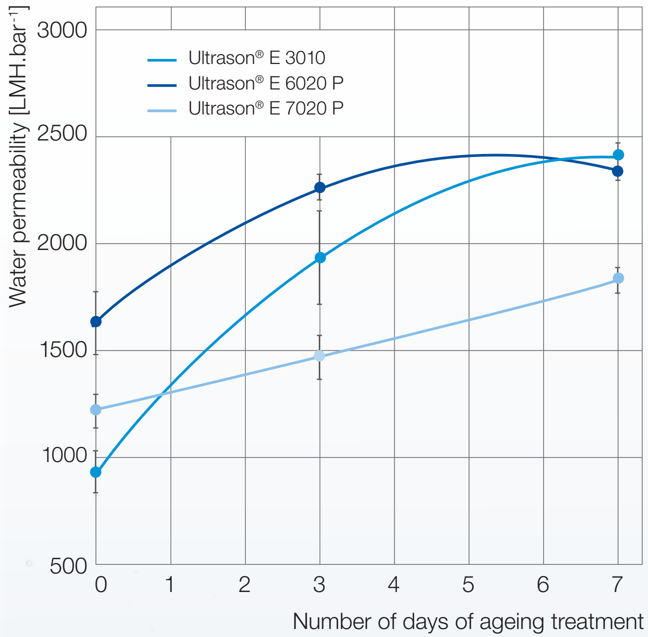
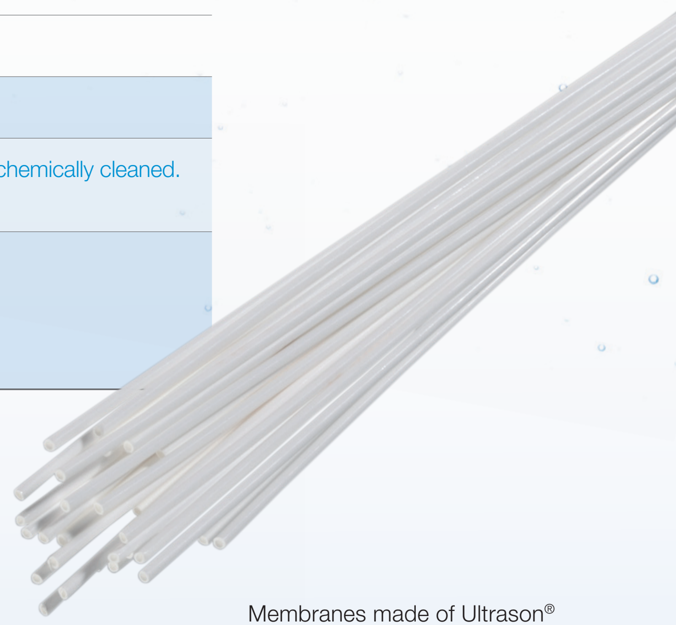


Fig. 2: Effect of NaOCl treatment on water permeability of hollow fibers made of different Ultrason® E grades (testing conditions: 2000 ppm NaOCl solution at pH=8, seven days)

Physical properties of PESU lead to better membrane performance than PVDF

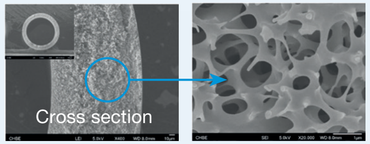
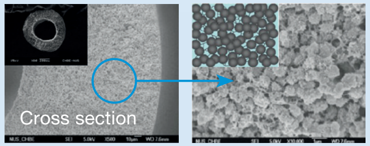
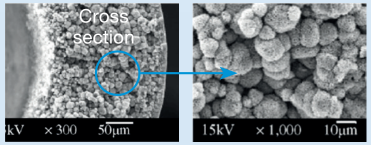
Polymer	PESU	PVDF
Type	Amorphous	Semi-crystalline
Density [g/cm^3]	1.37	1.79
	Cost effective: with the same membrane geometry, 30 % less material is required for PESU membranes, typically even more, since PVDF membranes often have a higher wall thickness.	
Water uptake [%]	2.2	< 0.1
	PESU has up to 2x higher water permeability and shows less fouling. → less chemical cleaning and lower trans-membrane pressure (TMP) than with PVDF	
Operating pH	1-13	1-10
	PESU has excellent stability over a broad pH-range.	
Filtration mode	Inside-out	Outside-in
	With PESU, there is no "dead-zone" area for inside-out configuration and a smaller volume has to be chemically cleaned. → less chemicals needed	
Mechanical properties ▪ Elongation modulus [MPa] ▪ Stress at yield [MPa] ▪ Elongation at break [%]	 2,700 90 > 30	 2,200 55 > 60

Table 2: Comparison of physical properties of PESU and PVDF



Membranes made of Ultrason®

Membrane performance can easier be controlled with PESU than with PVDF

Polymer	PESU	PVDF	
Processing	**Non-solvent induced phase separation (NIPS)**	**Non-solvent induced phase separation (NIPS)**	**Temperature induced phase separation (TIPS)**
Configuration	Hollow fiber		
Membrane morphology	 Strong fiber – high porosity with interconnected pores	 Weak fiber – spherulitic globules due to crystallinity	 Strong fiber – low porosity, interconnected globules
Porosity	75-80 %	60-70 %	60-70 %
Water permeability [LMH/bar]	UF: >1,000	UF: 500-600	
Pore size [μm]	0.02 and below (narrow)	0.015 – 0.2 (broader distribution, not exactly UF rating)	
Virus removal $(LRV)_{10}$	≥ 4	0.5 - 3.5 (lower than drinking water LRV requirement = 4)	

Photos: PVDF-NIPS: J. Membr. Sci. 340 (2009) 192 - 205; TIPS: Sep. Pur. Tech 63 (2008) 415

Table 3: Influence of polymer processing conditions of PESU and PVDF on key membrane properties

PVDF fiber breakage is a fact

The fiber breakage in PVDF has been observed regularly in the past due to:

- Abrasion by small particles during air scour
- Too high flux applied, leading to stress by hydraulic turbulences
- Mechanical fatigue (PVDF is more brittle than PP)

To resolve the issue of fiber breakage (table 4), the thickness of PVDF membranes has been increased by mayor membrane manufacturers.

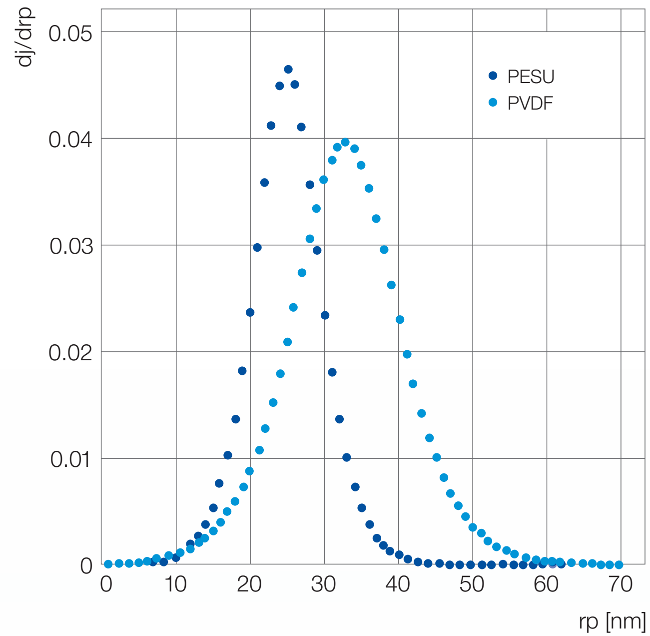
PESU membranes demonstrate narrower pore size distribution and higher virus removal than PVDF

The membrane effectiveness for virus removal is strongly determined by the pore size and the pore size distribution. By nature, the standard PESU formulation can easily produce narrower pore size distribution with a higher log virus removal value (LRV ≥ 4) for drinking water applications than PVDF (figure 3).

Manufacturer	Fiber outer diameter [mm]	Fiber inner diameter [mm]	Fiber thickness [mm]
P	2.0 - 4.1	1.1 - 2.6	0.45 - 0.75
S1	1.9	0.80	0.56
S2	0.95	0.47	0.24
S3	1.1	0.66	0.22
E1	0.8	0.50	0.15
E2	1.3	0.65	0.325

Source: Stratton et al., Membrane Fiber Breakage: Case Histories, Probable Causes, and Possible Solutions, 2011, American Water Works Association Membrane Technology Conference Proceedings

Table 4: Thickness of MF/UF hollow fibers produced by the top PVDF membrane manufacturers



Pathogens to be removed out of drinking water:

- Bacteria: 200 - 30,000 nm
- Giardia cyst: 10,000 nm
- Crystosporidium: 4,000 nm
- MS2 Phage (virus): 27 - 34 nm

The removal efficiency for MS2 can be used to derive the log removal value (LRV)

Fig. 3: The usage of Ultrason® results in membranes with narrower pore size distribution and higher virus removal as compared to PVDF.

PESU leads to higher virus removal with UF membranes than PVDF

Major PESU membrane producers generally supply UF membranes with LRV ≥ 4. PVDF producers show lower LRV which does not comply with the standard for drinking water and requires super-chlorination to deactivate the remaining virus (see table 5). Furthermore, the permeability of PESU membranes is approximately two times that of PVDF resulting in significant energy savings due to lower pressure requirements.

Membrane manufacturer	Model	Polymer	Nominal type	Max. flux [lmh]	MS2 virus LRV	Max. TMP [bar]
Hydranautics	HYDRAcap 60	**PESU**	UF	119	>4	1.2
Inge	Dizzer	**PESU**	UF	156	3.5	2.0
Norit	SXL 225	**PESU**	UF	127	>4	2.1
GE-Zenon	ZW 500	supported PVDF	–	85	2.5	–
GE-Zenon	ZW 1000	PVDF	UF	93	3.5	0.8
DOW	SFX 2860	PVDF	UF	102	2.5	2.1
Pall	Microza	PVDF	**MF**	204	0.5	3.0
Siemens Memcor	S10 V, L10 V, L20 V	PVDF	UF	88	1.5	1.5
Toray	HF S-2020	PVDF	UF	202	1.5	2.0

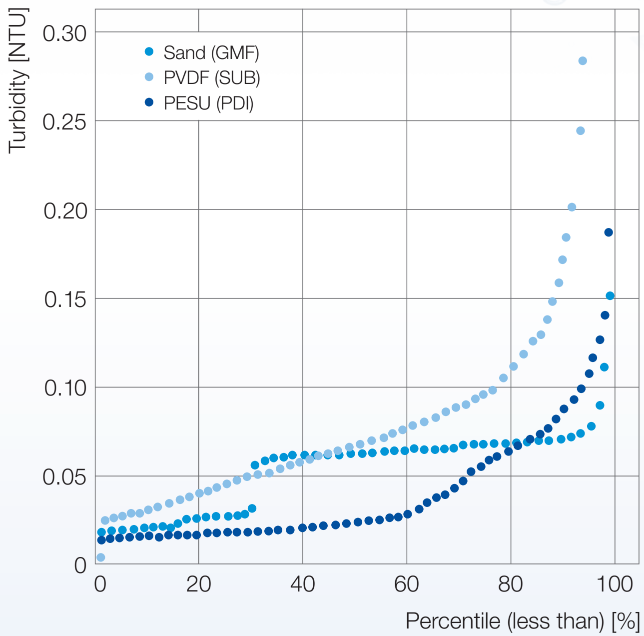
Source: Alternative Filtration Technology Summary, California Department of Health Services (CDPH), DDWEM Technical Programs Branch www.cdph.ca.gov/certlic/drinkingwater, September 2008

Table 5: Log removal value of ultrafiltration membranes made of PESU and PVDF (LRV 4 means only 1 out of 10,000 viruses can pass the membrane)

Lower water turbidity of ultrafiltration pre-treatment for reverse osmosis process with PESU membranes than PVDF

Due to narrower pore size distribution, UF membranes made of PESU allow higher feed water quality for RO as compared to PVDF leading to less fouling on RO membrane and higher productivity of RO process. Therefore, PESU has a 70 % market share in UF pre-treatment for the RO process.

Municipal water treatment facility in Rötgen (Germany)



Source: R Huehmer et al, Proceedings of AMTA Membrane Conf, Las Vegas, July 2007

Fig. 4: Quality of pretreated water for RO using PESU, PVDF and sand (GMF = granular media filtration; SUB = sub-merged; PDI = pressure driven inside out)

Ultrafiltration membranes (Multibore membrane by Inge)

Membranes made of PESU show better alkaline resistance than those made of PVDF

Sulfone polymers have outstanding chemical resistance towards alkali which are typically used for membrane cleaning. There is no degradation observed on the molecular weight of PSU, PESU or PPSU membranes when exposed to 10 % caustic soda at 40 °C for 1,000 hours. However, the molecular weight of PVDF degrades significantly by 35 % in such alkaline conditions.

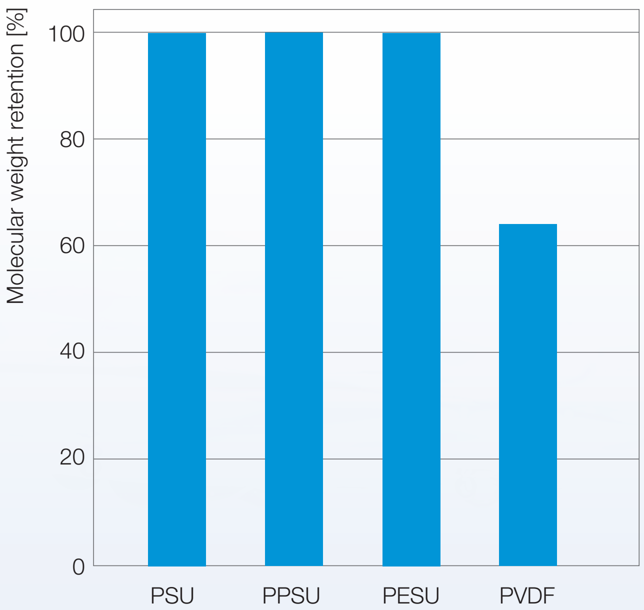


Fig 5: Retention of molecular weight of PSU, PPSU, PESU and PVDF membranes after 1,000 h immersion in caustic soda (NaOH, 10 %, 40 °C)

T-Rack 30 UF module assembly by Inge

Success story of Ultrason® E 6020 P for sustainable water supply

For its portable LifeStraw® Family water purification system, Vestergaard Frandsen uses UF hollow fibers made of Ultrason® E 6020 P. The fibers are bundled into an approximately 30 cm long plastic housing. The easy-to-use plastic design simplifies on-site conversion of large quantities of dirty water into potable water to be used in rural areas.

Advantages of LifeStraw® Family:

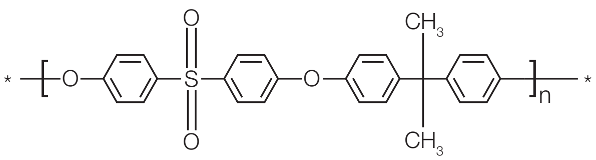
- Food contact approvals (FDA, EU)
- Secure removal of parasites, bacteria and viruses (LRV 4)
- Simple handling without chemicals (e.g. chlorine), electricity, pumps etc.
- Produced water complies with EPA standards for drinking water

(Photo by Vestergaard Frandsen)

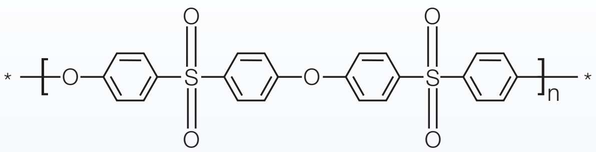
Ultrason®
Product portfolio

The products for membrane applications are offered in various molecular weights as granules (PSU, PPSU) or in form of porous flakes (PESU) for faster dissolution.

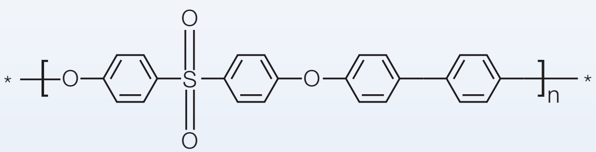
Ultrason® S (PSU: polysulfone)



Ultrason® E (PESU: polyethersulfone)



Ultrason® P (PPSU: polyphenylenesulfone)



	Unit	Ultrason® S (PSU)		Ultrason® E (PESU)				Ultrason® P (PPSU)
Grade		3010	6010	2020 P	3010	6020 P	7020 P	3010
Appearance		pellets		flakes	pellets	flakes		pellets
Specific gravity	g/cm³	1.23		1.37				1.29
Moisture absorption (23 °C, 50 % r.h.)	%	0.3		1				0.6
Surface energy**	mN/m	40.2		44.8				42.7
Mean molecular weights								
Viscosity number (VN)	ml/g	72	81	56	66	81	105	71
Mw (GPC)*	g/mol	53,000	60,000	48,000	52,000	72,000	90,000	48,000
Dispersity (Mw/MN)		3.7	3.9	2.7	3.0	3.4	3.7	2.7
Thermal								
Glass transition temperature	°C	187		225				220

Table 6: Ultrason® product range for membrane applications

*PSU: THF/PS standard;
PESU, PPSU: DMAc/PMMA standard
** Owens, Wendt

Selected Product Literature for Ultrason®:

- Ultrason® E, S, P – Product Brochure
- Ultrason® E, S, P – Product Range
- Ultrason® – Membrane Applications
- Ultrason® – Injection Molding
- Ultrason® – Special Products
- From the Idea to Production – The Aqua® Plastics Portfolio for the Sanitary and Water Industries
- Stylish, durabel and safe: Ultrason® for household and catering
- High-performance and durable reverse osmosis (RO) membranes with BASF's polysulfone (PSU) Ultrason® S – Processing guide

Note

The data contained in this publication are based on our current knowledge and experience. In view of the many factors that may affect processing and application of our product, these data do not relieve processors from carrying out own investigations and tests; neither do these data imply any guarantee of certain properties, nor the suitability of the product for a specific purpose. Any descriptions, drawings, photographs, data, proportions, weights etc. given herein may change without prior information and do not constitute the agreed contractual quality of the product. It is the responsibility of the recipient of our products to ensure that any proprietary rights and existing laws and legislation are observed. (June 2022)

Explore the full potential of Ultrason® and find the suitable grade for your application!
Ultrason® Product Selector on www.ultrason.basf.com

Further information on Ultrason® can be found on the internet:
www.ultrason.basf.com

Please visit our websites:
www.plastics.basf.com

Request of brochures:
plas.com@basf.com

If you have technical questions on the products, please contact the Ultra-Infopoint:

Ultra Infopoint
+49 621 60-78780
ultraplaste.infopoint@basf.com

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