

Process for hydrolytically depolymerizing a polyamide

The present invention relates to hydrolytically depolymerizing a polyamide 6 wherein an aqueous stream which is generated downstream of the hydrolytic depolymerization reaction is at least partially recycled back to the hydrolysis reaction, leading to an increase in yield in ϵ -caprolactam.

Polyamide, and in particular polyamide 6 being characterized by the formula $(-\text{NH}-(\text{CH}_2)_5-\text{CO}-)_n$, can be found in numerous materials, such as packaging, engineering plastics from automotive and textile filaments. The latter represents about 40 % of the polyamide 6 global market. At present, only a very small part of the textile filaments is recycled while it represents a significant percentage of the global CO_2 emissions. There is thus a need to recycle polyamide 6 from such materials. Processes for alkaline depolymerizing a polyamide exists. Further, the processes in the art are energy-intensive processes. Further, said materials which are subjected to such recycling processes often contain other polymeric compounds such as polyamide 6.6, polyurethane, polyester, polyethylene terephthalate or the like, which usually complicates the recycling. Therefore, there is the need to provide an improved process for hydrolytically depolymerizing polyamide 6 which is contained in a material which, in addition to polyamide 6, also contains at least one other polymeric compound other than polyamide 6.

Surprisingly, it was found that the process of the present invention wherein polyamide 6 is hydrolytically depolymerized and wherein the feedstock which is subjected to said hydrolytic depolymerization process contains at least one further polymeric compound allows for increasing the yield in the valuable product ϵ -caprolactam, the monomeric compound resulting from depolymerizing polyamide 6. Yet further, the process of the present invention permits to reduce the overall energy consumption compared to known processes which permits to reduce the CO_2 footprint and costs.

Therefore, the present invention relates to a process for hydrolytically depolymerizing polyamide 6, the process comprising

- (i) providing a chemical feedstock F comprising the polyamide 6 and further comprising at least one further organic polymeric compound;
- (ii) providing a liquid aqueous stream S_W ;
- (iii) admixing the chemical feedstock F provided according to (i) with the stream S_W provided according to (ii) and subjecting the obtained mixture to polyamide 6 depolymerization conditions in a chemical reaction unit U_R , the polyamide 6 depolymerization conditions comprising a polyamide 6 depolymerization temperature T_D and a polyamide 6 depolymerization pressure p_D , obtaining an aqueous stream S_E leaving U_R , the stream S_E comprising ϵ -caprolactam and one or more decomposition products of one or more of the at least one further organic polymeric compound;
- (iv) generating an aqueous stream S_R comprising at least part of the water and at least part of at least one of the one or more decomposition products comprised in the stream S_E , said stream S_R being depleted in ϵ -caprolactam compared to the stream S_E ;

- (v) feeding at least part of the aqueous stream S_R back to the chemical reaction unit U_R as part of the aqueous stream S_W .

5 Preferably according to the present invention, no polyamide 6 depolymerization catalyst such as a mineral acid, such as one or more of hydrochloric acid, nitric acid, sulphuric acid and phosphoric acid, and/or a zinc salt such as zinc chloride, zinc acetate or zinc triflate is added for preparing the mixture to be subjected to hydrolytic polyamide 6 depolymerisation conditions.

10 In addition to the ϵ -caprolactam monomeric compound, the stream S_E preferably further comprises one or more of ϵ -caprolactam dimer and aminocaproic acid.

The at least one further organic polymeric compound which is comprised in the feedstock F according to (i) preferably comprises one or more of at least one polyamide 6.6; at least one semiaromatic polyamide including one or more of polyamide 6T and polyamide 6I; at least one polyethylene terephthalate; at least one polyurethane; at least one polyester; at least one polyether; at least one polyvinyl chloride; at least one natural fiber material such as wool and cotton; at least one cellulose material; at least one natural elastomer; at least one synthetic elastomer; at least one copolymer of two or more of said polymeric compounds including statistical copolymers, gradient copolymers, alternating copolymers, block copolymers, and graft
15 copolymers; and at least one rubber material comprising one or more of at least one natural rubber material and at least one synthetic rubber material.
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According to the present invention, it is preferred that at least one of the at least one further organic polymeric compound comprised in the chemical feedstock is a polyurethane. Therefore,
25 preferably, the present invention relates to a process for hydrolytically depolymerizing polyamide 6, the process comprising

- (i) providing a chemical feedstock F comprising the polyamide 6 and at least one polyurethane and optionally further comprising at least one further organic polymeric compound;
- (ii) providing a liquid aqueous stream S_W ;
- 30 (iii) admixing the chemical feedstock F provided according to (i) with the stream S_W provided according to (ii) and subjecting the obtained mixture to polyamide 6 depolymerization conditions in a chemical reaction unit U_R , the polyamide 6 depolymerization conditions comprising a polyamide 6 depolymerization temperature T_D and a polyamide 6 depolymerization pressure p_D , obtaining an aqueous stream S_E leaving U_R , the stream S_E
35 comprising ϵ -caprolactam and one or more decomposition products of one or more of the at least one further organic polymeric compound;
- (iv) generating an aqueous stream S_R comprising at least part of the water and at least part of at least one of the one or more decomposition products comprised in the stream S_E , said stream S_R being depleted in ϵ -caprolactam compared to the stream S_E ;
- 40 (v) feeding at least part of the aqueous stream S_R back to the chemical reaction unit U_R as part of the aqueous stream S_W ;

wherein the at least one further organic polymeric compound according to (i) preferably comprises one or more of at least one polyamide 6.6; at least one semiaromatic polyamide

- including one or more of polyamide 6T and polyamide 6I; at least one polyethylene terephthalate; at least one polyester; at least one polyether; at least one polyvinyl chloride; at least one natural fiber material such as wool and cotton; at least one cellulose material; at least one natural elastomer; at least one synthetic elastomer; at least one copolymer of two or more of said
- 5 polymeric compounds including statistical copolymers, gradient copolymers, alternating copolymers, block copolymers, and graft copolymers; and at least one rubber material comprising one or more of at least one natural rubber material and at least one synthetic rubber material.
- In addition to the at least one further organic polymeric compound, the feedstock F according to
- 10 (i) may further comprise other chemical compounds. These compounds may comprise, for example, one or more of at least one pigment material and at least one glass fiber material. By way of example, such pigment materials may comprise organic or inorganic pigments such as TiO_2 .
- 15 According to (iv), an aqueous stream S_R comprising at least part of the water and at least part of at least one of the one or more decomposition products obtained according to (iii) is generated which stream S_R is then recycled according to (v). Preferably, the stream S_R , more preferably the at least one of the one or more decomposition products which are comprised in the stream S_R , comprises one or more of at least one amine, at least one ketone, at least one ether, at least one
- 20 amide, and at least one alcohol, wherein the at least one amine preferably comprises one or more of at least one aliphatic amine and at least one aromatic amine, the at least one ketone preferably comprises at least one aliphatic ketone, the at least one ether preferably comprises at least one aliphatic ether, the at least one amide preferably comprises at least one aliphatic amide, and the at least one alcohol preferably comprises at least one aliphatic alcohol.
- 25 Further preferably, the stream S_R , more preferably the at least one of the one or more decomposition products which are comprised in the stream S_R , comprises one or more of aniline, 4-aminotoluene, 2,2-dimethoxy-3-methyl butane, 3,3-dimethoxypentane, dimethylacetamide, tripropylamine, 2-octanol, 2,2-dimethoxybutane, and cyclopentanone, wherein aniline is
- 30 preferably comprised in the stream S_R , preferably in the at least one of the one or more decomposition products which are comprised in the stream S_R .
- Yet further preferably, the stream S_R comprises ϵ -caprolactam and preferably one or more of
- 35 N-ethylcaprolactam and 3-(2-oxazepan-1-yl)propanal.
- As mentioned above, the at least one further organic polymeric compound comprised in the feedstock F preferably comprises at least one polyurethane, and the stream S_E comprises one or more decomposition products of one or more of said at least one polyurethane, and wherein the stream S_R comprises at least part of at least one of said one or more decomposition products.
- 40 More preferably, one or more of the at least one polyurethane comprised in the feedstock F are prepared from at least one aniline-based isocyanate, wherein the one or more decomposition products comprised in S_R comprise aniline.

Generally, the chemical feedstock F may consist of one single material or from several different material, i.e. it consists of w chemical materials M_j with $j=1..w$ and $w \geq 1$. Further according to the present invention, preferably at least one of the chemical materials M_j , more preferably every chemical material M_j comprises, preferably consists of a waste material, said waste material
 5 preferably comprising, more preferably consisting of, one or more of at least one textile waste material and at least one engineering plastics waste material, more preferably comprising, more preferably consisting of at least one textile waste material. If $w > 1$, the respective two or more materials may have different chemical compositions which are not subject to any specific restrictions with the proviso that the chemical feedstock F exhibits the composition as discussed
 10 above.

While there are no specific respective restrictions, it is preferred that from 10 to 100 weight-%, more preferably from 20 to 100 weight-%, more preferably from 30 to 100 weight-%, more preferably from 40 to 100 weight-%, more preferably from 50 to 100 weight-%, more preferably
 15 from 60 to 100 weight-% of the feedstock F consist of the polyamide 6 and the at least one further organic polymeric compound. Generally respectively conceivable ranges may be, for example, from 70 to 100 weight-% or from 80 to 100 weight-% or from 90 to 100 weight-% or from 95 to 100 weight-% or from 98 to 100 weight-% or from 99 to 100 weight-%. Preferred ranges of the weight ratio of polyamide 6 relative to the at least one further organic polymeric compound are
 20 from 1:1 to 10:1 or from 1.2:1 to 8:1 or from 1.4:1 to 6:1 or from 1.6:1 to 4:1 or from 1.8:1 to 3:1.

Regarding the chemical feedstock F which is provided according to (i), it is preferred that it is provided in solid form, more preferably in the form of particles such as granules.

- 25 Preferably, the particle size distribution of said particles is characterized by one or more of the following pairs of values, more preferably by two or more of the following pairs of values, more preferably by the following three pairs of values:
- a D10 value of the particle width in the range of from in the range of from 0.3 to 15 mm and a D10 value of the particle length in the range of from 0.3 to 15 mm;
 - 30 - a D50 value of the particle width in the range of from in the range of from 0.5 to 20 mm and a D50 value of the particle length in the range of from 0.5 to 20 mm;
 - a D90 value of the particle width in the range of from in the range of from 0.8 to 30 mm and a D90 value of the particle length in the range of from 0.8 to 30 mm.
- 35 More preferred pairs of values are, for example:
- a D10 value of the particle width in the range of from in the range of from 2 to 4 mm and a D10 value of the particle length in the range of from 3.5 to 5.5 mm;
 - a D50 value of the particle width in the range of from in the range of from 2.5 to 4.5 mm and a D50 value of the particle length in the range of from 4 to 7 mm;
 - 40 - a D90 value of the particle width in the range of from in the range of from 3 to 5 mm and a D90 value of the particle length in the range of from 4.5 to 8.5 mm.

The term "particle" as used in this context of the present invention comprises optionally pre-

formed granules, and also comprises shredded pieces.

According to a first alternative of the present invention, the chemical feedstock F is admixed according to (iii) in solid form with the liquid aqueous stream S_W . According to this alternative, it

5 may be preferred that process wherein (i) further comprises

(i) providing the chemical feedstock F in solid form wherein said feedstock has a temperature below the melting point of polyamide 6;

wherein (ii) further comprises

(ii) providing the liquid aqueous stream S_W , wherein from 90 to 100 weight-% of S_W consist of water and wherein S_W has a temperature which is below the melting point of polyamide 6;

wherein (iii) further comprises

(iii) feeding the solid chemical feedstock provided according to (i) and the liquid aqueous stream S_W provided according to (ii) into the chemical reaction unit U_R , obtaining a mixture, and subjecting said mixture in U_R to polyamide 6 depolymerization conditions comprising a polyamide 6 temperature T_D wherein T_D is higher than the temperature of the feedstock provided according to (i) and lower than the temperature of the liquid aqueous stream S_W provided according to (ii).

According to a second alternative of the present invention, providing the chemical feedstock F according to (i) comprises bringing the chemical feedstock F from the solid form to a liquid form, and wherein according to (iii), the chemical feedstock F is admixed in liquid form with the liquid aqueous stream S_W . Regarding this alternative, the process of the present invention may preferably comprise

(a) providing the feedstock F in a solid form;

(b) melting in a melting unit U_M the solid feedstock F, obtaining a liquid stream S_M having a temperature T_{SM} at a pressure p_{SM} ;

(c) providing a liquid aqueous stream S_W having a temperature T_{SW} at a pressure p_{SW} ;

(d) admixing in a pre-reaction unit U_{PR} the stream S_M with the stream S_W , obtaining a liquid reaction feed stream S_F having a temperature T_{SF} at a pressure p_{SF} ;

(e) feeding the stream S_F into the chemical reaction unit U_R and subjecting it to polyamide 6 depolymerization conditions in a chemical reaction unit U_R , the polyamide 6 depolymerization conditions comprising a polyamide 6 depolymerization temperature T_D and a polyamide 6 depolymerization pressure p_D , obtaining an aqueous stream S_E leaving U_R , the stream S_E comprising ϵ -caprolactam and one or more decomposition products of one or more of the at least one further organic polymeric compound.

According to this method comprising steps (a) to (e), it is preferred that $0.8 \leq T_{SF}/T_D \leq 1.05$ and $0.9 \leq p_{SF}/p_D \leq 1.05$. It is further preferred that $0.6 \leq T_{SM}/T_{SF} \leq 1.05$ and $0.9 \leq p_{SM}/p_{SF} \leq 1.05$. Yet further, it is preferred that $0.8 \leq T_{SW}/T_{SF} \leq 1.3$ and $0.9 \leq p_{SW}/p_{SF} \leq 1.05$. Further according to this method comprising steps (a) to (e), the pre-reaction unit U_{PR} according to (d) comprises,

preferably consists of, a mixing unit, preferably a static mixing unit. The term "static mixing unit" as used herein refers to an arrangement of mixing elements which are installed in a pipe or duct, and which operate essentially without moving parts, preferably entirely without moving parts.

According to the present invention, it may be preferred that said mixing unit is configured as a

suitable pipe junction of the pipe for the stream S_M and the pipe for the stream S_W , wherein no specific mixing elements are present. Yet further, it is preferred that the melting unit U_M comprises a kneader or an extruder, more preferably an extruder, wherein more preferably, the melting unit U_M according to (ii) consists of an extruder, wherein more preferably, the extruder is a single-screw extruder or a twin-screw extruder, more preferably a twin-screw extruder. Yet further according to this method comprising steps (a) to (e), it is preferred that downstream of the melting unit U_M and upstream of the reaction unit U_R , a filtration unit U_F is arranged, preferably a filtration unit U_F for separating particles having a particle size in the range of from 100 to 500 micrometer, preferably in the range of from 200 to 400 micrometer, from the liquid stream S_M , wherein the process comprises passing the stream liquid stream S_M through U_F , prior to admixing according to (d).

Regarding the polyamide 6 depolymerisation conditions according to (iii), it is preferred that they comprise a polyamide 6 depolymerisation temperature T_D in the range of from 230 to 330 °C, more preferably in the range of from 250 to 320 °C, more preferably in the range of from 270 to 310 °C, such as in the range of from 270 to 280 °C or in the range of from 280 to 290 °C or in the range of from 290 to 300 °C or in the range of from 300 to 310 °C. The depolymerisation temperature T_D is the temperature of the liquid reaction mixture during (iii). Further regarding the polyamide 6 depolymerisation conditions according to (iii), it is preferred that they comprise a polyamide 6 depolymerisation pressure p_D in the range of from 40 to 140 bar, more preferably in the range of from 40 to 125 bar, more preferably in the range of from 40 to 110 bar, such as in the range of from 40 to 55 bar or in the range of from 55 to 70 bar or in the range of from 70 to 85 bar or in the range of from 85 to 100 bar or in the range of from 100 to 110 bar.

Regarding step (iii), it is preferred that the feedstock F and the stream S_W are admixed at a mixing ratio $(m_W/\text{kg}) / (m_P/\text{kg})$ in the range of from 1:1 to 20:1, preferably in the range of from 2:1 to 15:1, more preferably in the range of from 5:1 to 10:1, wherein m_W is the amount of water comprised in S_W and m_P is the amount of polyamide 6 comprised in the chemical feedstock F .

Regarding the chemical reaction unit U_R , it is preferred that it comprises z chemical reactors R_i , $i=1\dots z$, wherein z is in the range of from 1 to 10, preferably in the range of from 1 to 8, more preferably in the range of from 1 to 6, more preferably in the range of from 1 to 5, more preferably in the range of from 1 to 4, more preferably in the range of from 1 to 3. If $z > 1$, preferably at least 2 reactors R_i , more preferably z reactors R_i are serially coupled.

The overall residence time of the reaction mixture subjected to polyamide 6 depolymerization conditions in the chemical reaction unit U_R is in the range of from 15 to 800 minutes, preferably in the range of from 30 to 600 minutes, more preferably in the range of from 45 to 360 minutes, more preferably in the range of from 60 to 240 minutes. The term "overall residence time" as used in this context of the present invention refers to the sum of the residence times in all chemical reactors R_i mentioned above.

According to the present invention, it may be preferred, in particular as far as the method

- comprising steps (a) to (e) as described above is concerned, that if $z > 1$, at least 2 reactors R_i , preferably z reactors R_i are serially coupled, wherein the stream S_F is fed into R_i , with $i = 1$; an aqueous liquid stream S_i containing ϵ -caprolactam dissolved in water is removed from reactor R_i and fed into the reactor R_{i+1} , with $i < z$; and the aqueous liquid stream S_z containing
- 5 ϵ -caprolactam dissolved in water is removed from the reactor R_z as the stream S_E ; wherein in every reactor R_i , a depolymerization temperature T_{Di} at a depolymerization pressure p_{Di} is maintained, wherein, independently of each other, T_{Di} is in the range of from 230 to 330 °C and p_{Di} is in the range of from 40 to 140 bar, preferably wherein T_{Di} is in the range of from 250 to 320 °C and p_{Di} is in the range of from 40 to 125 bar, more preferably wherein T_{Di} is in the range of
- 10 from 270 to 310 °C and p_{Di} is in the range of from 40 to 110 bar. Preferably for $z > 1$, the z reactors R_i are vertically arranged, with R_1 being the top-most reactor and R_z being the bottom-most reactor, wherein S_i obtained from R_i is transferred to R_{i+1} by gravity, preferably by gravity only.
- 15 More preferably, at least 1, preferably z reactors R_i , are stirred tank reactors, wherein every stirred tank reactor R_i may preferably have, independently from each other, from 2 to 6 compartments, preferably from 2 to 5 compartments, more preferably from 2 to 4 compartments, said compartments preferably being serially, more preferably being serially and vertically arranged, wherein 2 adjacent compartments are separated by a divider which comprises at least
- 20 one flow-through opening. Said at least one compartment comprised in a reactor R_i may preferably comprise at least one agitator, wherein preferably every compartment of every reactor R_i comprises at least one agitator, wherein more preferably, every compartment of every reactor R_i comprises one agitator, wherein the process comprises agitating the depolymerization mixture in a given compartment for at least part of the time during subjecting to depolymerization
- 25 conditions in said compartment.

- Alternatively, regarding the specific design of said stirred tank reactors, it is particularly preferred according to the present invention that at least one stirred tank reactor R_i , preferably every stirred tank reactor R_i , has, independently from each other, preferably from 2 to 6 compartments, more
- 30 preferably from 2 to 5 compartments, more preferably from 2 to 4 compartments, said compartments preferably being serially, more preferably being serially and vertically arranged, wherein said reactor R_i comprises at least one agitator and wherein 2 adjacent compartments are formed by, and separated by, one or more suitable components of said agitator such as blades comprised in the agitator, wherein the process comprises agitating the depolymerization mixture
- 35 in a given compartment for at least part of the time during subjecting to depolymerization conditions in the reactor compartment.

- The polyamide 6 depolymerization conditions according preferably further comprise a total residence time t_D of the aqueous depolymerization mixture in the unit U_R , preferably in the z
- 40 reactors R_i , more preferably in the z stirred tank reactors, wherein at least 85 weight-%, preferably at least 90 weight-%, more preferably at least 95 weight-% of the aqueous depolymerization mixture have a t_D in the range of from 30 to 90 min. More preferably, for $z > 1$, the residence time of an aqueous depolymerization mixture in a reactor R_i is t_{Di} and wherein

$0.90 \leq (t_{Di} / t_{Di+1}) \leq 1.10$, preferably $0.95 \leq (t_{Di} / t_{Di+1}) \leq 1.05$.

- Preferably according to the present invention, generating the aqueous stream S_R according to (iv) comprises subjecting to the stream S_E obtained from the reaction unit U_R , optionally after
- 5 subjecting S_E to filtration, to thermal water separation, obtaining the stream S_R . While not being restricted to any particular method, it is preferred that said thermal water separation comprises one or more of evaporation and distillation, more preferably one or more of distillation and falling film evaporation. More preferably, generating the aqueous stream S_R according to (iv) comprises, more preferably consists of, distilling the stream S_E obtained from the reaction unit U_R , optionally
- 10 after subjecting S_E to filtration, obtaining the stream S_R . Said distilling is preferably carried out in a distillation column at a bottoms temperature preferably in the range of from 70 to 140 °C, more preferably in the range of from 80 to 120 °C, more preferably in the range of from 90 to 110 °C, and a top pressure preferably in the range of from 0.5 to 1.5 bar, more preferably in the range of from 0.7 to 1.2 bar, more preferably in the range of from 0.8 to 1.1 bar, wherein the stream S_R is
- 15 obtained at the top of the distillation column. Further, said distilling preferably comprises subjecting the vapor top stream to condensation, obtaining a liquid stream S_R , wherein at least a part of the liquid stream S_R is fed back to the chemical reaction unit U_R as part of the aqueous stream S_W according to (v). Said liquid stream S_R obtained from condensation may preferably be divided into 2 streams, wherein a first stream obtained from dividing is fed back to the chemical
- 20 reaction unit U_R as part of the aqueous stream S_W according to (v) and a second stream is fed back to the top of the distillation column, wherein the volume ratio of the first stream relative to the second stream is preferably in the range of from 10:1 to 0.5:1, more preferably in the range of from 7:1 to 1:1, more preferably in the range of from 5:1 to 2:1.
- 25 Also preferably according to (iv), the aqueous stream S_R is generated in the course of subjecting the stream S_E to one or more stages downstream of U_R according to which a stream S_{CPL} is prepared comprising purified ϵ -caprolactam which may then be suitably recycled to the material value chain, such as a starting material for preparing polyamide 6. Said one or more downstream purification stages which may further comprise one or more stages according to which heat
- 30 contained in the stream S_E is suitably recovered and, for example, used for at least partially meeting the heat demand of one or more of said downstream purification stages, may comprise, for example, the following sequence of stages:
- (A) passing the liquid aqueous stream S_E into an evaporation unit U_E , obtaining from S_E a liquid aqueous stream S_L comprising ϵ -caprolactam dissolved in water at a concentration c_{SL} with
- 35 $c_{SL} > c_{SR}$, and further obtaining from S_E one or more aqueous vapor streams S_V ;
- (B) passing the aqueous stream S_L into a heat-consuming purification unit U_P , obtaining from S_L a stream S_{CPL} comprising ϵ -caprolactam at a concentration c_{SCPL} with
- $c_{SCPL} \gg c_{SL}$, and further obtaining from S_L one or more aqueous streams S_{RW} , wherein at least part of the heat consumed in U_P is provided by at least one of the one or more
- 40 streams S_V , thereby obtaining from the at least one stream S_V at least one at least partially condensed aqueous stream S_{VW} ;
- (C) recycling, as the stream S_R , at least one stream S_{VW} at least partially and at least one stream S_{RW} at least partially to the reaction unit U_R .

The recycling according to (C) may preferably comprise

(C.1) feeding the at least one stream S_{VW} and the at least one stream S_{RW} into a water treatment unit U_W , obtaining from U_W at least one aqueous recycle stream S_R ;

5 (C.2) recycling the at least one aqueous stream S_R at least partially to the reaction unit U_R .

The water treatment unit U_W according to (C.1) may preferably comprise a water recovery unit U_{WR} and a waste water unit U_{WW} , wherein (x.1) further comprises

10 (C.1.1) feeding the at least one stream S_{VW} and the at least one stream S_{RW} into the water recovery unit U_{WR} , obtaining from U_{WR} the at least one aqueous recycle stream S_W and at least one aqueous stream S_{SW} ;

(C.1.2) feeding the at least one stream S_{SW} to the waste water unit U_{WW} , obtaining from U_{WW} , at least one waste water stream S_{WW} .

15 The purification unit U_P according to (B) may preferably comprise one or more of a heat-consuming water separation unit U_{WS} , a heat-consuming distillation unit U_D and a heat-consuming crystallization unit U_C , preferably two or more of a heat-consuming water separation unit U_{WS} , a heat-consuming distillation unit U_D and a heat-consuming crystallization unit U_C , more preferably a heat-consuming water separation unit U_{WS} , a heat-consuming distillation unit U_D and a heat-consuming crystallization unit U_C , wherein at least part of the heat consumed in one or more of
20 U_{WS} , U_D and U_C is provided by at least one of the one or more streams S_V .

Preferably, the process may comprise one or more of the following; more preferably at least two or more of the following; more preferably all of the following:

25 - obtaining at least one at least partially condensed aqueous stream S_{VW1} from U_{WS} ;
- obtaining at least one at least partially condensed aqueous stream S_{VW2} from U_D ;
- obtaining at least one at least partially condensed aqueous stream S_{VW3} from U_C ;
the process further comprising feeding one or more S_{VW1} , S_{VW2} and S_{VW3} ; preferably two or more S_{VW1} , S_{VW2} and S_{VW3} ; more preferably S_{VW1} , S_{VW2} and S_{VW3} into the water treatment unit U_W as
30 defined above.

Preferably, at least one of the streams S_{RW} is obtained from U_{WS} .

35 Preferably, the purification unit U_P may comprise a heat-consuming water separation unit U_{WS} , a heat-consuming distillation unit U_D and a heat-consuming crystallization unit U_C , the process comprising feeding the stream S_L comprising ϵ -caprolactam at a concentration c_{SL} to U_{WS} , obtaining from U_{WS} a stream U_{WS} comprising ϵ -caprolactam at a concentration c_{UWS} , feeding the stream S_{UWS} to the distillation unit U_D , obtaining from U_D a stream S_{UD} comprising ϵ -caprolactam at a concentration c_{UD} , and feeding the stream S_{UD} into the crystallization unit U_C , and obtaining
40 from U_C a stream S_{CPL} comprising ϵ -caprolactam at a concentration c_{SCPL} , wherein
 $c_{SL} < c_{UWS} < c_{UD} < c_{SCPL}$.

Preferably, the water separation unit U_{WS} may comprise at least two heat-consuming water

separation sub-units U_{WS1} and U_{WS2} , preferably two serially coupled heat-consuming water separation sub-units U_{WS1} and U_{WS2} , wherein the stream S_L is fed into U_{WS1} and wherein at least part of the heat consumed in one or more of U_{WS1} and U_{WS2} is provided by at least one of the one or more streams S_V .

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Preferably, the process may comprise one or more of the following, more preferably all of the following:

- obtaining at least one at least partially condensed aqueous stream S_{VW11} from U_{WS1} ;
- obtaining at least one at least partially condensed aqueous stream S_{VW12} from U_{WS2} .

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Preferably, at least one aqueous stream S_{RW1} is obtained from U_{WS1} and at least one aqueous stream S_{RW2} is obtained from U_{WS2} , and wherein at least one of S_{RW1} and S_{RW2} , preferably S_{RW1} and S_{RW2} are fed into U_W .

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Preferably, the evaporation unit U_E may comprise two or more evaporation sub-units, the process comprising obtaining at least two vapor streams S_{V1} and S_{V2} , passing the vapor stream S_{V1} to at least one heat-consuming unit and passing the vapor stream S_{V2} to at least one heat-consuming unit, wherein the vapor streams S_{V1} and S_{V2} differ from each other in either pressure and/or temperature.

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The present invention also relates to the use of an aqueous stream S_R or a part thereof, obtained by a process comprising

- (i) providing a chemical feedstock F comprising polyamide 6 and further comprising at least one further organic polymeric compound;
- 25 (ii) providing a liquid aqueous stream S_W ;
- (iii) admixing the feedstock F provided according to (i) with the stream S_W provided according to (ii) and subjecting the obtained mixture to polyamide 6 depolymerization conditions in a chemical reaction unit U_R , the polyamide 6 depolymerization conditions comprising a polyamide 6 depolymerization temperature T_D and a polyamide 6 depolymerization pressure p_D , obtaining an aqueous stream S_E leaving U_R , the stream S_E comprising ϵ -caprolactam and one or more decomposition products of one or more of the at least one further organic polymeric compound;
- 30 (iv) generating an aqueous stream S_R comprising at least part of the water and at least part of at least one of the one or more decomposition products, said stream S_R being depleted in ϵ -caprolactam compared to the stream S_E ;
- 35 as a recycle stream for increasing the ϵ -caprolactam yield of polyamide 6 depolymerization according to (iii).

Yet further, the present invention also relates to a method for increasing the ϵ -caprolactam yield of a polyamide 6 depolymerization reaction, the method comprising

- 40 (i) providing a chemical feedstock F comprising polyamide 6 and further comprising at least one further organic polymeric compound;
- (ii) providing a liquid aqueous stream S_W ;

- (iii) admixing the feedstock F provided according to (i) with the stream S_W provided according to (ii) and subjecting the obtained mixture to polyamide 6 depolymerization conditions in a chemical reaction unit U_R , the polyamide 6 depolymerization conditions comprising a polyamide 6 depolymerization temperature T_D and a polyamide 6 depolymerization pressure p_D , obtaining an aqueous stream S_E leaving U_R , the stream S_E comprising ϵ -caprolactam and one or more decomposition products of one or more of the at least one further organic polymeric compound;
- (iv) generating an aqueous stream S_R comprising at least part of the water and at least part of at least one of the one or more decomposition products, said stream S_R being depleted in ϵ -caprolactam compared to the stream S_E ;
- (v) feeding at least part of the aqueous stream S_R back to the chemical reaction unit U_R as part of the aqueous stream S_W .

Providing the chemical feedstock, and the materials M_j , respectively, may comprise an upstream sorting stage. In this regard, it is possible, for example, to spread collected waste material, preferably textile waste material and/or engineering plastics material, more preferably textile waste material on a conveyor, which spreading can be carried out either manually and/or mechanically. Thereafter, the respectively spread waste material is subjected to sorting, either by composition and/or by color. Sorting can be carried out either manually and/or optically. If carried out optically, the sorting preferably comprises an infrared sorting, more preferably a near-infrared sorting and/or a mid-infrared sorting. Optionally, prior to sorting, the waste material can be subjected to a suitable metal removing step. If a metal removing step is carried out, ferrous elements are preferably separated, for example by suitable magnetic means, and/or non-ferrous elements are preferably separated, for example by suitable eddy current separating means. After said sorting, the respectively obtained waste material can be subjected to a further treatment, such as cutting and/or milling.

The present invention is further illustrated by the following set of embodiments and combinations of embodiments resulting from the dependencies and back-references as indicated. In particular, it is noted that in each instance where a range of embodiments is mentioned, for example in the context of a term such as "The process of any one of embodiments 1 to 4", every embodiment in this range is meant to be explicitly disclosed for the skilled person, i.e. the wording of this term is to be understood by the skilled person as being synonymous to "The process of any one of embodiments 1, 2, 3 and 4". Further, it is explicitly noted that the following set of embodiments represents a suitably structured part of the general description directed to preferred aspects of the present invention, and, thus, suitably supports, but does not represent the claims of the present invention.

1. A process for hydrolytically depolymerizing polyamide 6, the process comprising
 - (i) providing a chemical feedstock F comprising the polyamide 6 and further comprising at least one further organic polymeric compound;
 - (ii) providing a liquid aqueous stream S_W ;

- (iii) admixing the chemical feedstock F provided according to (i) with the stream S_W provided according to (ii) and subjecting the obtained mixture to polyamide 6 depolymerization conditions in a chemical reaction unit U_R , the polyamide 6 depolymerization conditions comprising a polyamide 6 depolymerization temperature T_D and a polyamide 6 depolymerization pressure p_D , obtaining an aqueous stream S_E leaving U_R , the stream S_E comprising ϵ -caprolactam and one or more decomposition products of one or more of the at least one further organic polymeric compound;
- (iv) generating an aqueous stream S_R comprising at least part of the water and at least part of at least one of the one or more decomposition products comprised in the stream S_E , said stream S_R being depleted in ϵ -caprolactam compared to the stream S_E ;
- (v) feeding at least part of the aqueous stream S_R back to the chemical reaction unit U_R as part of the aqueous stream S_W .
2. The process of embodiment 1, wherein the stream S_E further comprises one or more of ϵ -caprolactam dimer and aminocaproic acid.
3. The process of embodiment 1 or 2, wherein the at least one further organic polymeric compound comprised in the feedstock F comprises one or more of at least one polyamide 6.6; at least one semiaromatic polyamide including one or more of polyamide 6T and polyamide 6I; at least one polyethylene terephthalate; at least one polyurethane; at least one polyester; at least one polyether; at least one polyvinyl chloride; at least one natural fiber material such as wool and cotton; at least one cellulose material; at least one natural elastomer; at least one synthetic elastomer; at least one copolymer of two or more of said polymeric compounds including statistical copolymers, gradient copolymers, alternating copolymers, block copolymers, and graft copolymers; and at least one rubber material comprising one or more of at least one natural rubber material and at least one synthetic rubber material.
4. The process of any one of embodiments 1 to 3, wherein the feedstock F comprises, in addition to the polyamide 6 and the at least one further organic polymeric compound, one or more of at least one pigment material and at least one glass fiber material.
5. The process of any one of embodiments 1 to 4, wherein the stream S_R , preferably the at least one of the one or more decomposition products which are comprised in the stream S_R , comprises one or more of at least one amine, at least one ketone, at least one ether, at least one amide, and at least one alcohol, wherein the at least one amine preferably comprises one or more of at least one aliphatic amine and at least one aromatic amine, the at least one ketone preferably comprises at least one aliphatic ketone, the at least one ether preferably comprises at least one aliphatic ether, the at least one amide preferably comprises at least one aliphatic amide, and the at least one alcohol preferably comprises at least one aliphatic alcohol.

6. The process of any one of embodiments 1 to 5, wherein the stream S_R , preferably the at least one of the one or more decomposition products which are comprised in the stream S_R , comprises one or more of aniline, 4-aminotoluene, 2,2-dimethoxy-3-methyl butane, 3,3-dimethoxypentane, dimethylacetamide, tripropylamine, 2-octanol, 2,2-dimethoxybutane, and cyclopentanone, wherein aniline is preferably comprised in the stream S_R , preferably in the at least one of the one or more decomposition products which are comprised in the stream S_R .
7. The process of any one of embodiments 1 to 6, wherein the stream S_R comprises ϵ -caprolactam and preferably one or more of N-ethylcaprolactam and 3-(2-oxazepan-1-yl)propanal.
8. The process of any one of embodiments 1 to 7, wherein the at least one further organic polymeric compound comprised in the feedstock comprises at least one polyurethane, wherein the stream S_E comprises one or more decomposition products of one or more of said at least one polyurethane, and wherein the stream S_R comprises at least part of at least one of said one or more decomposition products.
9. The process of embodiment 8, wherein one or more of the at least one polyurethane comprised in the feedstock F are prepared from at least one aniline-based isocyanate and wherein the one or more decomposition products comprised in S_R comprise aniline.
10. The process of any one of embodiments 1 to 9, wherein the chemical feedstock F provided according to (i) consists of w chemical materials M_j with $j=1..w$ and $w \geq 1$, wherein at least one of the chemical materials M_j , preferably every chemical material M_j comprises, preferably consists of a waste material, said waste material preferably comprising, more preferably consisting of, one or more of at least one textile waste material and at least one engineering plastics waste material, more preferably comprising, more preferably consisting of at least one textile waste material.
11. The process of any one of embodiments 1 to 10, wherein from 10 to 100 weight-%, preferably from 20 to 100 weight-%, more preferably from 30 to 100 weight-%, more preferably from 40 to 100 weight-%, more preferably from 50 to 100 weight-%, more preferably from 60 to 100 weight-% of the feedstock F consist of the polyamide and the at least one further organic polymeric compound.
12. The process of any one of embodiments 1 to 11, wherein according to (i), the feedstock F is provided in solid form, preferably in the form of particles, wherein the particle size distribution of said particles is preferably characterized by one or more of the following pairs of values, preferably by two or more of the following pairs of values, more preferably by the following three pairs of values:
 - a D10 value of the particle width in the range of from 0.3 to 15 mm and a D10 value of the particle length in the range of from 0.3 to 15 mm;

- a D50 value of the particle width in the range of from 0.5 to 20 mm and a D50 value of the particle length in the range of from 0.5 to 20 mm;
 - a D90 value of the particle width in the range of from 0.8 to 30 mm and a D90 value of the particle length in the range of from 0.8 to 30 mm.
- 5
13. The process of embodiment 12, wherein according to (iii), the feedstock F is admixed in solid form with the aqueous stream S_W .
- 10
14. The process of embodiment 12, wherein providing the feedstock F according to (i) comprises bringing the feedstock F from the solid form to a liquid form, preferably by subjecting the solid feedstock F to melt-extrusion, and wherein according to (iii), the feedstock F is admixed in liquid form with the aqueous stream S_W .
- 15
15. The process of any one of embodiments 1 to 14, wherein according to (iii), the polyamide 6 depolymerization temperature T_D is in the range of from 230 to 330 °C, preferably in the range of from 250 to 320 °C, more preferably in the range of from 270 to 310 °C.
- 20
16. The process of any one of embodiments 1 to 15, wherein according to (iii), the polyamide 6 depolymerization pressure p_D is in the range of from 40 to 140 bar, preferably in the range of from 40 to 125 bar, more preferably in the range of from 40 to 110 bar.
- 25
17. The process of any one of embodiments 1 to 16, wherein according to (iii), the feedstock F and the stream S_W are admixed at a mixing ratio $(m_W/kg) / (m_P/kg)$ in the range of from 1:1 to 20:1, preferably in the range of from 2:1 to 15:1, more preferably in the range of from 5:1 to 10:1, wherein m_W is the amount of water comprised in S_W and m_P is the amount of polyamide 6 comprised F.
- 30
18. The process of any one of embodiments 1 to 17, wherein the reaction unit U_R comprises z chemical reactors R_i , $i=1\dots z$, wherein z is in the range of from 1 to 10, preferably in the range of from 1 to 8, more preferably in the range of from 1 to 6, more preferably in the range of from 1 to 5, more preferably in the range of from 1 to 4, more preferably in the range of from 1 to 3.
- 35
19. The process of embodiment 18, wherein if $z > 1$, at least 2 reactors R_i , preferably z reactors R_i are serially coupled.
- 40
20. The process of any one of embodiments 1 to 19, wherein the overall residence time in the chemical reaction unit U_R is in the range of from 15 to 800 minutes, preferably in the range of from 30 to 600 minutes, more preferably in the range of from 45 to 360 minutes, more preferably in the range of from 60 to 240 minutes.
21. The process of any one of embodiments 1 to 20, being a continuous process, a semicontinuous process or a batch process.

22. The process of any one of embodiments 1 to 21, wherein generating the aqueous stream S_R according to (iv) comprises subjecting to the stream S_E obtained from the reaction unit U_R , optionally after subjecting S_E to filtration, to thermal water separation, obtaining the stream S_R .
23. The process of embodiment 22, wherein the thermal water separation comprises one or more of distilling and falling film evaporating.
24. The process of any one of embodiments 1 to 23, wherein generating the aqueous stream S_R according to (iv) comprises, preferably consists of, distilling the stream S_E obtained from the reaction unit U_R , optionally after subjecting S_E to filtration, obtaining the stream S_R .
25. The process of embodiment 24, wherein distilling is carried out in a distillation column at a bottoms temperature in the range of from 70 to 140 °C, preferably in the range of from 80 to 120 °C, more preferably in the range of from 90 to 110 °C, and a top pressure in the range of from 0.5 to 1.5 bar(abs), preferably in the range of from 0.7 to 1.2 bar(abs), more preferably in the range of from 0.8 to 1.1 bar(abs), wherein the stream S_R is obtained at the top of the distillation column.
26. The process of embodiment 25, wherein distilling comprises subjecting the vapor top stream to condensation, obtaining a liquid stream S_R , wherein at least a part of the liquid stream S_R is fed back to the chemical reaction unit U_R as part of the aqueous stream S_W according to (v).
27. The process of embodiment 26, wherein the liquid stream S_R obtained from condensation is divided into 2 streams, wherein a first stream obtained from dividing is fed back to the chemical reaction unit U_R as part of the aqueous stream S_W according to (v) and a second stream is fed back to the top of the distillation column, wherein the volume ratio of the first stream relative to the second stream is preferably in the range of from 10:1 to 0.5:1, more preferably in the range of from 7:1 to 1:1, more preferably in the range of from 5:1 to 2:1.
28. The process of any one of embodiments 1 to 21, wherein generating the aqueous stream S_R according to (iv) comprises
- (A) passing the liquid aqueous stream S_E into an evaporation unit U_E , obtaining from S_E a liquid aqueous stream S_L comprising ϵ -caprolactam dissolved in water at a concentration c_{SL} with $c_{SL} > c_{SR}$, and further obtaining from S_E one or more aqueous vapor streams S_V ;
- (B) passing the aqueous stream S_L into a heat-consuming purification unit U_P , obtaining from S_L a stream S_{CPL} comprising ϵ -caprolactam at a concentration c_{SCPL} with $c_{SCPL} \gg c_{SL}$, and further obtaining from S_L one or more aqueous streams S_{RW} , wherein at least part of the heat consumed in U_P is provided by at least one of the one

or more streams S_V , thereby obtaining from the at least one stream S_V at least one at least partially condensed aqueous stream S_{VW} ;

- (C) recycling, as the stream S_R , at least one stream S_{VW} at least partially and at least one stream S_{RW} at least partially to the reaction unit U_R .

5

29. Use of S_{CPL} , obtainable or obtained by a process according to embodiment 28, for preparing one or more of a polymer and a polymer product; or a method for preparing one or more of a polymer and a polymer product, said method comprising employing S_{CPL} , obtainable or obtained by a process according to embodiment 28 as a starting material.
30. The use or the method of embodiment 29, wherein the polymer, or the polymer product, or the polymer and the polymer product is or are in the form of at least one of a granulate, a strand, a rod, a plate, a pipe, a foil, a layer, a film, a sheet, a fiber, a filament, a coating, an extruded article, a molded article, a soft foam, a half-rigid foam and a rigid foam.
31. The use or the method of embodiment 29 or 30, wherein the polymer, or the polymer product, or the polymer and the polymer product comprises or comprise polyamide 6 and optionally at least one further polymeric compound, said polyamide 6 being at least partially obtainable or obtained from S_{CPL} , said S_{CPL} being obtainable or obtained by a process according to embodiment 28, wherein the at least one further polymeric compound preferably comprises one or more of at least one polyamide 6.6; at least one semiaromatic polyamide including one or more of polyamide 6T and polyamide 6I; at least one polyethylene terephthalate; at least one polyurethane; at least one polyester; at least one polyether; at least one polyvinyl chloride; at least one natural fiber material such as wool and cotton; at least one cellulose material; at least one natural elastomer; at least one synthetic elastomer; at least one copolymer of two or more of said polymeric compounds including statistical copolymers, gradient copolymers, alternating copolymers, block copolymers, and graft copolymers; and at least one rubber material comprising one or more of at least one natural rubber material and at least one synthetic rubber material.
32. The use or the method of any one of embodiments 29 to 31, wherein the polymer, or the polymer product, or the polymer and the polymer product is or are one of the following or a part of one of the following:
- a part of a car, preferably a cylinder head cover, an engine cover, a housing for a charge air cooler, a charge air cooler flap, an intake pipe, an intake manifold, a connector, a gear wheel, a fan wheel, a cooling water box, a housing or a housing part for a heat exchanger, a coolant cooler, a charge air cooler, a thermostat, a water pump, a radiator, a fastening part or a part of a battery system for electromobility, a dashboard, a steering column switch, a seat, a headrest, a center console, a transmission component, a door module, a car exterior for an A, a B, a C or a D pillar cover, a spoiler, a door handle, an exterior mirror, a windscreen wiper, a windscreen wiper protection housing, a decorative grill, a cover strip, a roof rail, a window frame,

- a sunroof frame, an antenna panel, a headlight, a taillight, an airbag, and/or a cushion;
- a cloth, an apparel, preferably a shirt, trousers, a pullover, a boot, a shoe, a shoe sole, a tight and/or or jacket;
 - 5 - an electrical part, preferably an electrical component, an electronic passive component, an electronic active component, a printed circuit board, a housing component, a foil, a line, a switch such as a microswitch, a plug, a socket, a distributor, a relay, a resistor, a capacitor, an inductor, a bobbin, a lamp, a diode such as an LED, a transistor, a connector, a regulator, an integrated circuit (IC), a
 - 10 processor, a controller, a memory, a sensor, a microbutton, a semiconductor, a reflector housing for example for light-emitting diodes, a fastener for an electrical and/or an electronic component, a spacer, a bolt, a strip, a slide-in guide, a screw, a nut, a film hinge, a snap hook (snap-in), and/or a spring tongue;
 - 15 - a consumer and/or a pharmaceutical product, preferably a tennis string, a climbing rope, a bristle, a brush, an artificial grass, a 3D printing filament, a grass trimmer, a zipper, a hook and loop fastener, a paper machine clothing, an extrusion coating, a fishing line, a fishing net, an offshore line and rope, a vial, a syringe, an ampoule, a bottle, a sliding element, a spindle nut, a chain conveyor, a plain bearing, a roller, a wheel, a gear, a roller, a ring gear, a screw and spring damper, a hose, a pipeline, a
 - 20 cable sheathing, a socket, a switch, a cable tie, a fan wheel, a carpet, a box and/or a bottle for cosmetics, a mattress, a cushion, an insulation;
 - a packaging for the food industry, preferably a mono- and/or multi-layer blown film, a cast film (mono- and/or multi-layer), a biaxially stretched film, a laminating film.
- 25 33. The use or the method of any one of embodiments 29 to 32, wherein the polymer, or the polymer product, or the polymer and the polymer product contains or contain polyamide 6, obtainable or obtained from S_{CPL} , said S_{CPL} being obtainable or obtained by a process according to embodiment 28, in an amount of 1 weight-% or more, preferably 2 weight-% or more, more preferably 5 weight-% or more, more preferably 15 weight-% or more, more
- 30 preferably 30 weight-% or more, more preferably 40 weight-% or more, more preferably 60 weight-% or more, more preferably 80 weight-% or more, more preferably 90 weight-% or more, more preferably 95 weight-% or more; and/or in an amount of 100 weight-% or less, preferably 95 weight-% or less, more preferably 90 weight-% or less, more preferably 50 weight-% or less, more preferably 25 weight-% or less, more preferably 10 weight-% or less.
- 35 34. Use of an aqueous stream S_R or a part thereof, obtained by a process comprising
- (i) providing a chemical feedstock F comprising polyamide 6 and further comprising at least one further organic polymeric compound;
 - 40 (ii) providing a liquid aqueous stream S_W ;
 - (iii) admixing the feedstock F provided according to (i) with the stream S_W provided according to (ii) and subjecting the obtained mixture to polyamide 6 depolymerization conditions in a chemical reaction unit U_R , the polyamide 6 depolymerization

- conditions comprising a polyamide 6 depolymerization temperature T_D and a polyamide 6 depolymerization pressure p_D , obtaining an aqueous stream S_E leaving U_R , the stream S_E comprising ϵ -caprolactam and one or more decomposition products of one or more of the at least one further organic polymeric compound;
- 5 (iv) generating an aqueous stream S_R comprising at least part of the water and at least part of at least one of the one or more decomposition products, said stream S_R being depleted in ϵ -caprolactam compared to the stream S_E ;
- as a recycle stream for increasing the ϵ -caprolactam yield of polyamide 6 depolymerization according to (iii).
- 10 35. A method for increasing the ϵ -caprolactam yield of a polyamide 6 depolymerization reaction, the method comprising
- (i) providing a chemical feedstock F comprising polyamide 6 and further comprising at least one further organic polymeric compound;
- 15 (ii) providing a liquid aqueous stream S_W ;
- (iii) admixing the feedstock F provided according to (i) with the stream S_W provided according to (ii) and subjecting the obtained mixture to polyamide 6 depolymerization conditions in a chemical reaction unit U_R , the polyamide 6 depolymerization conditions comprising a polyamide 6 depolymerization temperature T_D and a
- 20 polyamide 6 depolymerization pressure p_D , obtaining an aqueous stream S_E leaving U_R , the stream S_E comprising ϵ -caprolactam and one or more decomposition products of one or more of the at least one further organic polymeric compound;
- (iv) generating an aqueous stream S_R comprising at least part of the water and at least part of at least one of the one or more decomposition products, said stream S_R being
- 25 depleted in ϵ -caprolactam compared to the stream S_E ;
- (v) feeding at least part of the aqueous stream S_R back to the chemical reaction unit U_R as part of the aqueous stream S_W .

30 As far as the embodiment 33 is concerned, the respective amounts are preferably determined based on identity preservation and/or segregation and/or mass balance and/or book and claim chain of custody models, more preferably based on mass balance, more preferably the International Sustainability and Carbon Certification (ISCC) standard.

35 As far as the embodiments 29 to 33 are concerned, preparing the polymer, the polymer product, or the polymer and the polymer product may comprise one or more synthesis steps and can be performed by conventional synthesis and technics well known to the person skilled in the art. Examples of the synthesis steps are described in "Industrial Organic Chemistry", 3rd volume, Wiley-VCH, 1997; ISBN: 978-3-527-28838-0; „Kunststoffhandbuch“, 11 volumes in 17 sub-volumes, Carl Hanser Verlag, especially volume 6, „Polyamide“, 1st edition, 1966; "Injection

40 Molding Reference Guide, 4th edition, CreateSpace Independent Publishing Platform, 2011, ISBN: 978-1466407824; WO 2008/155271 A1 and WO 2013/139827 A1, each of which is incorporated herein by reference.

In the context of the present invention, a term “X is one or more of A, B and C”, wherein X is a given feature and each of A, B and C stands for specific realization of said feature, is to be understood as disclosing that X is either A, or B, or C, or A and B, or A and C, or B and C, or A and B and C. In this regard, it is noted that the skilled person is capable of transfer to above
5 abstract term to a concrete example, e.g. where X is a chemical element and A, B and C are concrete elements such as Li, Na, and K, or X is a temperature and A, B and C are concrete temperatures such as 10 °C, 20 °C, and 30 °C. In this regard, it is further noted that the skilled person is capable of extending the above term to less specific realizations of said feature, e.g. “X is one or more of A and B” disclosing that X is either A, or B, or A and B, or to more specific
10 realizations of said feature, e.g. “X is one or more of A, B, C and D”, disclosing that X is either A, or B, or C, or D, or A and B, or A and C, or A and D, or B and C, or B and D, or C and D, or A and B and C, or A and B and D, or B and C and D, or A and B and C and D.

The term „bar“ as used in the context of the present invention refers to „bar(abs)“, i.e. bar
15 (absolute), sometimes also referred to “bara”.

The term “textile material” as used herein covers textile raw materials and non-textile raw materials that are processed by various methods into linear, planar and spatial structures. It concerns the linear textile structures produced from them, such as yarns, twisted yarns and
20 ropes, the sheet-like textile structures, such as woven fabrics, knitted fabrics, braids, stitch-bonded fabrics, nonwovens and felts, and the three-dimensional textile structures, i.e. body structures, such as textile hoses, stockings or textile semi-finished products; and it further concerns those finished products which, using the aforementioned products, are brought into a saleable condition by making up, opening up and/or other operations for onward transmission to
25 the processor, the trade or the end consumer.

The term “textile waste material” covers a textile material as defined above, the inherent value of which has been consumed from the perspective of its current holder and, thus, is an end-of-life material for said holder.
30

The term “engineering plastics” as used herein refers to high-performance plastics grades which possess physical properties enabling them to perform for prolonged use in structural applications, over a wide temperature range, under mechanical stress, and in difficult chemical and physical environments used for example to fabricate plastic parts replacing traditional engineering
35 materials like metals and ceramics. Engineering plastics specifically apply in the fabrication of mechanical parts across several industries such as automotive, medical, electrical and electronics, aerospace, construction and consumer products.

The term “engineering plastics waste material” as used herein covers an engineering plastics material as defined above, the inherent value of which has been consumed from the perspective
40 of its current holder and, thus, is an end-of-life material for said holder.

Preferred aspects of the present invention are further illustrated in the Figure 1 and the Examples as described hereinunder.

Description of the figures

5

Fig. 1 shows the results of the experiments according to runs 1 to 10 as described in Table 2 above, in particular with regard to the total yield of the caprolactam species (i) ϵ -caprolactam monomer, (ii) ϵ -caprolactam dimer and (iii) aminocaproic acid. In the diagram according to Fig. 1, the number of the respective run is shown on the x axis, the corresponding total yield (in %) is shown on the y axis. A linear regression is included (dotted line) which further highlights the increase in yield over time.

10

Examples

15 A textile waste material M containing about 65 weight-% polyamide 6 and further containing at least one further organic polymeric material including a polyurethane which was prepared from an aniline-based isocyanate was subjected as feedstock F to polyamide 6 depolymerization as follows:

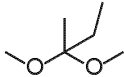
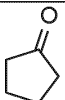
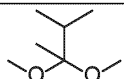
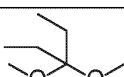
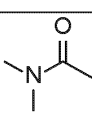
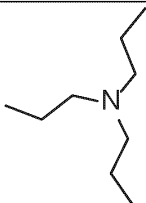
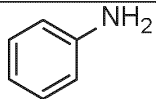
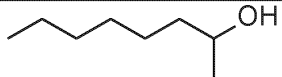
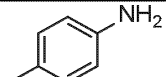
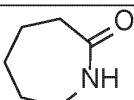
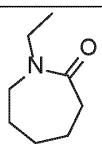
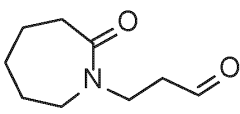
20 1.2 kg of the material M were provided in the form of solid granules having a diameter of in the range of from 1 to 4 mm. This material was put in an autoclave U_R having an inner volume of 20 dm³ together with 10 kg of a liquid aqueous phase S_W having a composition as indicated in the table below. The autoclave was then closed and the granule / aqueous phase mixture was heated within 2 to 4 hours from ambient temperature to a polyamide depolymerization
25 temperature T_D of 270 °C at a pressure of 55 – 60 bar(abs). This temperature was maintained for a residence time of 140 min. The respectively obtained depolymerization reaction mixture S_E was then cooled to ambient temperature. After having discharged the reaction mixture S_E from the autoclave, S_E was filtered through a 50 μ m sieve.

30 The resulting filtered solution S_E was then subjected to distillation in a distillation column at a bottoms temperature of 106 °C, a top temperature of 100 °C and a top pressure of 1013 mbar(abs). The vapor top stream obtained from the distillation column was condensed, and the obtained liquid stream S_R was divided into 2 streams so that 25 volume-% of S_R were fed back to the top of the column and 75 volume-% of S_R were fed back as part of S_W in the next run, i.e. as
35 feed to the autoclave U_R (reflux ratio 1:3). The bottoms stream obtained from U_R , the raw ϵ -caprolactam solution, had a water content of about 30 weight-%, an ϵ -caprolactam content of from 4 to 5 weight-%, an ϵ -caprolactam dimer content of from 0.05 to 0.1 weight-% and an aminocaproic acid content of from 0.9 to 1.4 weight-%; and the stream S_R had an ϵ -caprolactam content of about 0.045 weight-%, determined via GC analysis.

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The liquid stream S_R obtained from condensation as described above contained to following compounds, as determined via GC analysis (mean area contents, based on values obtained from runs 1 to 10):

Table 1Decomposition products comprised in the stream S_R

Chemical Structure	Chemical Name	Area-% GC	mg/kg**
	2,2-dimethoxybutane	< 0.01	< 1
	cyclopentanone	< 0.01	< 1
	2,2-dimethoxy-3-methylbutane	5.125	170
	3,3-dimethoxypentane		
	dimethylacetamide	< 0.01	< 1
	tripropylamine	< 0.01	< 1
	aniline	63.124	2150
	2-octanol	0.491	30
	4-aminotoluene	6.508	220
	ε-caprolactam	15.000	510
	N-ethylcaprolactam	0.815	30
	3-(2-oxoazepan-1-yl)propanal	2.273	80

According to the present invention and as described above, 75 volume-% of S_R were fed back as part of S_W in the next run, i.e. as feed to the autoclave U_R . In this regard, 10 consecutive polyamide depolymerization reactions were carried out in the autoclave. In the first run, the aqueous stream S_W consisted of 10 kg fresh DI water, and the resulting product stream S_E was subjected, after filtration, to a distillation as described above leading to a top vapor stream S_R from 75 volume-% were fed back to U_R as part of the aqueous stream S_W employed for the second run. Since the total mass of the stream S_W employed for the second run was also 10 kg, only a part of S_W consisted of fresh water, with the reminder consisting of said 75 volume-% of S_R . This procedure was repeated also for the following runs 3 to 10, as summarized in the following table. After the 10th run, the process was stopped.

Further in the following table, the respective yields of ϵ -caprolactam species for each run are shown, wherein, as far as these species are concerned, ϵ -caprolactam dimer and aminocaproic acid are taken into account in addition to ϵ -caprolactam (monomer). The term "yield" as used in this context of the present invention is defined – for each run – as the mass of the respective component contained in the stream S_R obtained in this run, divided by the mass of polyamide 6 contained in the material M used as starting material for this run. The following results were obtained:

Table 2

Yields as obtained from runs 1 to 10

run [#]	mass [kg] of part of stream S_R recycled / used for next run [#]	yield [%]			
		total	ϵ -capro- lactam monomer	ϵ -capro- lactam dimer	amino capronic acid
1	8.8 / 2	80.74	65.6	0.85	14.29
2	9.7 / 3	84.28	65.36	1.01	17.9
3	8.8 / 4	83.15	63.61	0.9	18.65
4	9.1 / 5	81.25	62.87	0.91	17.74
5	8.8 / 6	not determined			
6	9.3 / 7	84.9	67.83	1.21	15.85
7	9.0 / 8	85.37	68.78	1.25	15.34
8	8.7 / 9	88.3	71.21	1.35	15.73
9	9.6 / 10	88.6	69.45	1.47	17.68
10	9.1 / -	90.35	71.23	1.43	17.69

As can be derived from the results shown in the table above which are further illustrated by Fig. 1, the total yield in all ϵ -caprolactam species and in particular the yield in ϵ -caprolactam monomer statistically increases over time, i.e. the longer the process runs (the more consecutive runs are carried out), the higher is the respective yield. This result obtained from the consecutive batch runs is also a model of a continuous process for which, therefore, essentially the same result (increase in yield) will have to be expected.

GC analysis measurements according to present invention were carried out as follows:

The analysis was performed on a standard GC instrument equipped with a split/splitless injector and an FID. The injection volume was 1 μ L (microL) at a split ratio of 15:1. The injector temperature was 250 °C. The instrument was operated in constant pressure mode at 14.5 psi (about 1 bar), and nitrogen was used as carrier gas. Separation was performed on a Wax 52 CB column, 50 m x 0.32 mm, 1.2 μ m from Agilent Technologies. The temperature program started with a ramp from 80 °C to 185 °C at a heating rate of 7 °C/min, and a hold time at 185 °C for 30 min. A second ramp was from 185 °C to 200 °C at a heating rate of 7 °C/min, and a hold time at 200 °C for 5 min. The detector (Flame Ionization Detector, FID) temperature was 250 °C. Evaluation of purity values was based on area-% distribution, corrected by the content of water determined by Carl Fisher Method.

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Claims

1. A process for hydrolytically depolymerizing polyamide 6, the process comprising
 - (i) providing a chemical feedstock F comprising the polyamide 6 and further comprising at least one further organic polymeric compound;
 - (ii) providing a liquid aqueous stream S_W ;
 - (iii) admixing the chemical feedstock F provided according to (i) with the stream S_W provided according to (ii) and subjecting the obtained mixture to polyamide 6 depolymerization conditions in a chemical reaction unit U_R , the polyamide 6 depolymerization conditions comprising a polyamide 6 depolymerization temperature T_D and a polyamide 6 depolymerization pressure p_D , obtaining an aqueous stream S_E leaving U_R , the stream S_E comprising ϵ -caprolactam and one or more decomposition products of one or more of the at least one further organic polymeric compound;
 - (iv) generating an aqueous stream S_R comprising at least part of the water and at least part of at least one of the one or more decomposition products comprised in the stream S_E , said stream S_R being depleted in ϵ -caprolactam compared to the stream S_E ;
 - (v) feeding at least part of the aqueous stream S_R back to the chemical reaction unit U_R as part of the aqueous stream S_W .
2. The process of claim 1, wherein the stream S_E further comprises one or more of ϵ -caprolactam dimer and aminocaproic acid.
3. The process of claim 1 or 2, wherein the at least one further organic polymeric compound comprised in the feedstock F comprises one or more of at least one polyamide 6.6; at least one semiaromatic polyamide including one or more of polyamide 6T and polyamide 6I; at least one polyethylene terephthalate; at least one polyurethane; at least one polyester; at least one polyether; at least one polyvinyl chloride; at least one natural fiber material such as wool and cotton; at least one cellulose material; at least one natural elastomer; at least one synthetic elastomer; at least one copolymer of two or more of said polymeric compounds including statistical copolymers, gradient copolymers, alternating copolymers, block copolymers, and graft copolymers; and at least one rubber material comprising one or more of at least one natural rubber material and at least one synthetic rubber material.
4. The process of any one of claims 1 to 3, wherein the stream S_R , preferably the at least one of the one or more decomposition products which are comprised in the stream S_R , comprises one or more of at least one amine, at least one ketone, at least one ether, at least one amide, and at least one alcohol, wherein the at least one amine preferably comprises one or more of at least one aliphatic amine and at least one aromatic amine, the at least one ketone preferably comprises at least one aliphatic ketone, the at least one ether preferably comprises at least one aliphatic ether, the at least one amide preferably comprises at least one aliphatic amide, and the at least one alcohol preferably comprises at least one aliphatic alcohol.

5. The process of any one of claims 1 to 4, wherein the stream S_R , preferably the at least one of the one or more decomposition products which are comprised in the stream S_R , comprises one or more of aniline, 4-aminotoluene, 2,2-dimethoxy-3-methyl butane, 3,3-dimethoxypentane, dimethylacetamide, tripropylamine, 2-octanol, 2,2-dimethoxybutane, and cyclopentanone, wherein aniline is preferably comprised in the stream S_R , preferably in the at least one of the one or more decomposition products which are comprised in the stream S_R .
6. The process of any one of claims 1 to 5, wherein the stream S_R comprises ϵ -caprolactam and preferably one or more of N-ethylcaprolactam and 3-(2-oxazepan-1-yl)propanal.
7. The process of any one of claims 1 to 6, wherein the at least one further organic polymeric compound comprised in the feedstock comprises at least one polyurethane, wherein the stream S_E comprises one or more decomposition products of one or more of said at least one polyurethane, and wherein the stream S_R comprises at least part of at least one of said one or more decomposition products, wherein one or more of the at least one polyurethane comprised in the feedstock F are preferably prepared from at least one aniline-based isocyanate and wherein the one or more decomposition products comprised in S_R comprise aniline.
8. The process of any one of claims 1 to 7, wherein the chemical feedstock F provided according to (i) consists of w chemical materials M_j with $j=1..w$ and $w \geq 1$, wherein at least one of the chemical materials M_j , preferably every chemical material M_j comprises, preferably consists of a waste material, said waste material preferably comprising, more preferably consisting of, one or more of at least one textile waste material and at least one engineering plastics waste material, more preferably comprising, more preferably consisting of at least one textile waste material, wherein preferably from 10 to 100 weight-%, more preferably from 20 to 100 weight-%, more preferably from 30 to 100 weight-%, more preferably from 40 to 100 weight-%, more preferably from 50 to 100 weight-%, more preferably from 60 to 100 weight-% of the feedstock F consist of the polyamide and the at least one further organic polymeric compound.
9. The process of claim 8, wherein the feedstock F is admixed according to (iii) in solid form with the aqueous stream S_W , or wherein providing the feedstock F according to (i) comprises bringing the feedstock F from the solid form to a liquid form, preferably by subjecting the solid feedstock F to melt-extrusion, and wherein according to (iii), the feedstock F is admixed in liquid form with the aqueous stream S_W ; wherein according to (iii), the feedstock F and the stream S_W are preferably admixed at a mixing ratio $(m_W/kg) / (m_P/kg)$ in the range of from 1:1 to 20:1, more preferably in the range of from 2:1 to 15:1, more preferably in the range of from 5:1 to 10:1, wherein m_W is the amount of water comprised in S_W and m_P is the amount of polyamide 6 comprised F.

10. The process of any one of claims 1 to 9, wherein according to (iii), the polyamide 6 depolymerization temperature T_D is in the range of from 230 to 330 °C, preferably in the range of from 250 to 320 °C, more preferably in the range of from 270 to 310 °C, wherein according to (iii), the polyamide 6 depolymerization pressure p_D is in the range of from 40 to 140 bar, preferably in the range of from 40 to 125 bar, more preferably in the range of from 40 to 110 bar, and wherein the overall residence time in the chemical reaction unit U_R is in the range of from 15 to 800 minutes, preferably in the range of from 30 to 600 minutes, more preferably in the range of from 45 to 360 minutes, more preferably in the range of from 60 to 240 minutes.
11. The process of any one of claims 1 to 10, wherein generating the aqueous stream S_R according to (iv) comprises subjecting to the stream S_E obtained from the reaction unit U_R , optionally after subjecting S_E to filtration, to thermal water separation, obtaining the stream S_R , wherein the thermal separation preferably comprises one or more of distilling and falling film evaporating.
12. The process of any one of claims 1 to 10, wherein generating the aqueous stream S_R according to (iv) comprises distilling the stream S_E obtained from the reaction unit U_R , optionally after subjecting S_E to filtration, obtaining the stream S_R , wherein distilling is carried out in a distillation column at a bottoms temperature preferably in the range of from 70 to 140 °C, more preferably in the range of from 80 to 120 °C, more preferably in the range of from 90 to 110 °C, and a top pressure preferably in the range of from 0.5 to 1.5 bar(abs), more preferably in the range of from 0.7 to 1.2 bar(abs), more preferably in the range of from 0.8 to 1.1 bar(abs), wherein the stream S_R is obtained at the top of the distillation column;
wherein distilling preferably comprises subjecting the vapor top stream to condensation, obtaining a liquid stream S_R , wherein at least a part of the liquid stream S_R is fed back to the chemical reaction unit U_R as part of the aqueous stream S_W according to (v), wherein the liquid stream S_R obtained from condensation is optionally divided into 2 streams, wherein a first stream obtained from dividing is fed back to the chemical reaction unit U_R as part of the aqueous stream S_W according to (v) and a second stream is fed back to the top of the distillation column, wherein the volume ratio of the first stream relative to the second stream is preferably in the range of from 10:1 to 0.5:1, more preferably in the range of from 7:1 to 1:1, more preferably in the range of from 5:1 to 2:1.
13. The process of any one of claims 1 to 10, wherein generating the aqueous stream S_R according to (iv) comprises
- (A) passing the liquid aqueous stream S_E into an evaporation unit U_E , obtaining from S_E a liquid aqueous stream S_L comprising ϵ -caprolactam dissolved in water at a concentration c_{SL} with $c_{SL} > c_{SR}$, and further obtaining from S_E one or more aqueous vapor streams S_V ;
- (B) passing the aqueous stream S_L into a heat-consuming purification unit U_P , obtaining from S_L a stream S_{CPL} comprising ϵ -caprolactam at a concentration c_{SCPL} with

- $C_{SCPL} \gg C_{SL}$, and further obtaining from S_L one or more aqueous streams S_{RW} , wherein at least part of the heat consumed in U_P is provided by at least one of the one or more streams S_V , thereby obtaining from the at least one stream S_V at least one at least partially condensed aqueous stream S_{VW} ;
- 5 (C) recycling, as the stream S_R , at least one stream S_{VW} at least partially and at least one stream S_{RW} at least partially to the reaction unit U_R .
14. Use of S_{CPL} , obtainable or obtained by a process according to claim 13, for preparing one or more of a polymer and a polymer product, wherein the polymer, or the polymer product, or the polymer and the polymer product is or are in the form of at least one of a granulate, a strand, a rod, a plate, a pipe, a foil, a layer, a film, a sheet, a fiber, a filament, a coating, an extruded article, a molded article, a soft foam, a half-rigid foam and a rigid foam; and wherein the polymer, or the polymer product, or the polymer and the polymer product comprises or comprise polyamide 6 and optionally at least one further polymeric compound, said polyamide 6 being at least partially obtainable or obtained from S_{CPL} , said S_{CPL} being obtainable or obtained by a process according to claim 13, wherein the at least one further polymeric compound preferably comprises one or more of at least one polyamide 6.6; at least one semiaromatic polyamide including one or more of polyamide 6T and polyamide 6I; at least one polyethylene terephthalate; at least one polyurethane; at least one polyester; at least one polyether; at least one polyvinyl chloride; at least one natural fiber material such as wool and cotton; at least one cellulose material; at least one natural elastomer; at least one synthetic elastomer; at least one copolymer of two or more of said polymeric compounds including statistical copolymers, gradient copolymers, alternating copolymers, block copolymers, and graft copolymers; and at least one rubber material comprising one or more of at least one natural rubber material and at least one synthetic rubber material; wherein the polymer, or the polymer product, or the polymer and the polymer product is or are preferably one of the following or a part of one of the following:
- a part of a car, preferably a cylinder head cover, an engine cover, a housing for a charge air cooler, a charge air cooler flap, an intake pipe, an intake manifold, a connector, a gear wheel, a fan wheel, a cooling water box, a housing or a housing part for a heat exchanger, a coolant cooler, a charge air cooler, a thermostat, a water pump, a radiator, a fastening part or a part of a battery system for electromobility, a dashboard, a steering column switch, a seat, a headrest, a center console, a transmission component, a door module, a car exterior for an A, a B, a C or a D pillar cover, a spoiler, a door handle, an exterior mirror, a windscreen wiper, a windscreen wiper protection housing, a decorative grill, a cover strip, a roof rail, a window frame, a sunroof frame, an antenna panel, a headlight, a taillight, an airbag, and/or a cushion;
 - a cloth, an apparel, preferably a shirt, trousers, a pullover, a boot, a shoe, a shoe sole, a tight and/or or jacket;
 - an electrical part, preferably an electrical component, an electronic passive component, an electronic active component, a printed circuit board, a housing component, a foil, a line, a switch such as a microswitch, a plug, a socket, a

distributor, a relay, a resistor, a capacitor, an inductor, a bobbin, a lamp, a diode such as an LED, a transistor, a connector, a regulator, an integrated circuit (IC), a processor, a controller, a memory, a sensor, a microbutton, a semiconductor, a reflector housing for example for light-emitting diodes, a fastener for an electrical and/or an electronic component, a spacer, a bolt, a strip, a slide-in guide, a screw, a nut, a film hinge, a snap hook (snap-in), and/or a spring tongue;

- a consumer and/or a pharmaceutical product, preferably a tennis string, a climbing rope, a bristle, a brush, an artificial grass, a 3D printing filament, a grass trimmer, a zipper, a hook and loop fastener, a paper machine clothing, an extrusion coating, a fishing line, a fishing net, an offshore line and rope, a vial, a syringe, an ampoule, a bottle, a sliding element, a spindle nut, a chain conveyor, a plain bearing, a roller, a wheel, a gear, a roller, a ring gear, a screw and spring damper, a hose, a pipeline, a cable sheathing, a socket, a switch, a cable tie, a fan wheel, a carpet, a box and/or a bottle for cosmetics, a mattress, a cushion, an insulation;

- a packaging for the food industry, preferably a mono- and/or multi-layer blown film, a cast film (mono- and/or multi-layer), a biaxially stretched film, a laminating film.

15. Use of an aqueous stream S_R or a part thereof, obtainable or obtained by a process comprising

(i) providing a chemical feedstock F comprising polyamide 6 and further comprising at least one further organic polymeric compound;

(ii) providing a liquid aqueous stream S_W :

(iii) admixing the feedstock F provided according to (i) with the stream S_W provided according to (ii) and subjecting the obtained mixture to polyamide 6 depolymerization conditions in a chemical reaction unit U_R , the polyamide 6 depolymerization conditions comprising a polyamide 6 depolymerization temperature T_D and a polyamide 6 depolymerization pressure p_D , obtaining an aqueous stream S_E leaving U_R , the stream S_E comprising ϵ -caprolactam and one or more decomposition products of one or more of the at least one further organic polymeric compound;

(iv) generating an aqueous stream S_R comprising at least part of the water and at least part of at least one of the one or more decomposition products, said stream S_R being depleted in ϵ -caprolactam compared to the stream S_E ;

as a recycle stream for increasing the ϵ -caprolactam yield of polyamide 6 depolymerization according to (iii).