

Process for separating high boilers from polyamide 6 depolymerization mixtures

The present invention relates to a process for separating high boiling compounds from a stream which comprises the high boiling compounds and ϵ -caprolactam; this stream is preferably
5 obtained from the depolymerization of polyamide contained in a solid material, wherein this material is preferably a waste material. Further, the present invention relates to said process which, downstream of the high boiler separation, comprises further purification of ϵ -caprolactam, leading to a stream comprising highly purified ϵ -caprolactam. Yet further, the present invention relates to the respectively obtained highly purified ϵ -caprolactam and its use as an educt
10 material, preferably for preparing polyamide 6. Therefore, the present invention in particular relates to a recycle loop of ϵ -caprolactam.

Polyamide, and in particular polyamide 6 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
15 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. The purification process for ϵ -caprolactam downstream of the depolymerization step is not a straight-forward task, for example due to the various possible chemical compositions of
20 waste materials comprising polyamide 6 which form the educt materials for the recycling process.

It was found that said waste materials will contain certain compounds which, either prior to or after depolymerization of polyamide 6, lead to a stream comprising ϵ -caprolactam and
25 compounds having a higher boiling point than ϵ -caprolactam. Due to possibly different chemical compositions of said waste material, however, these compounds having a higher boiling point than ϵ -caprolactam will usually differ from time to time, both with regard to the content in the stream to be purified and in chemical nature. Therefore, there is a need for a robust process which is suitable for purifying crude ϵ -caprolactam streams comprising said high boiling
30 compounds and which allows for dealing with different qualities of streams to be purified.

Therefore, the present invention relates to a process for separating one or more organic compounds X from an aqueous liquid stream S_{L0} comprising monomeric ϵ -caprolactam and said one or more compounds X, the process comprising
35 (i) providing the stream S_{L0} having a temperature T_{L0} and exhibiting a total concentration $c_{L0}(X)$ of the one or more compounds X and a concentration $c_{L0}(C)$ of monomeric ϵ -caprolactam;
(ii) producing in an evaporation unit U_{E1} from the stream S_{L0} an aqueous at least partially vaporous stream S_{V1} and a liquid stream S_{L1} , comprising
40 (ii.1) passing the stream S_{L0} provided according to (i) into the unit U_{E1} , preparing in the unit U_{E1} from the stream S_{L0} an evaporation mixture M_{E1} having an evaporation temperature T_{E1} at an evaporation pressure p_{E1} with $T_{E1} > T_{L0}$, wherein the one or

- more one organic compounds X have a boiling point T_{BX} and ϵ -caprolactam has a boiling point T_{BC} with $T_{BX} > T_{E1} \geq T_{BC}$ at the evaporation pressure p_{E1} ;
- (ii.2) removing the stream S_{V1} from the evaporation unit U_{E1} , the stream S_{V1} having a temperature T_{V1} with $T_{V1} \leq T_{E1}$ and exhibiting a total concentration $c_{V1}(X)$ of one or more compounds X and a concentration $c_{V1}(C)$ of monomeric ϵ -caprolactam with $c_{V1}(C) > c_{L0}(C)$ and $c_{V1}(X) < c_{L0}(X)$;
- (ii.3) removing the stream S_{L1} from the evaporation unit U_{E1} , the stream S_{L1} having a temperature T_{L1} with $T_{L1} = T_{E1}$ and exhibiting a total concentration $c_{L1}(X)$ of one or more compounds X and a concentration $c_{L1}(C)$ of monomeric ϵ -caprolactam with $c_{L1}(C) < c_{E1}(C)$ and $c_{L1}(X) > c_{L0}(X)$;
- (iii) producing in a separation unit U_{S1} from the stream S_{V1} an aqueous vapor stream S_{V2} and a liquid stream S_{L2} , comprising
- (iii.1) passing the stream S_{V1} removed from the evaporation unit U_{E1} according to (ii.2), optionally after cooling, into the separation unit U_{S1} and subjecting the stream S_{V1} , optionally the stream after cooling, in the separation unit U_{S1} to separation conditions;
- (iii.2) removing the stream S_{V2} from the separation unit U_{S1} , the stream S_{V2} having a temperature T_{V2} with $T_{L0} < T_{V2} \leq T_{V1}$ and exhibiting a total concentration $c_{V2}(X)$ of one or more compounds X and a concentration $c_{V2}(C)$ of monomeric ϵ -caprolactam;
- (iii.3) removing the stream S_{L2} from the separation unit U_{S1} , the stream S_{L2} having a temperature T_{L2} with $T_{L2} = T_{V2}$ and exhibiting a total concentration $c_{L2}(X)$ of one or more compounds X and a concentration $c_{L2}(C)$ of monomeric ϵ -caprolactam with $c_{L2}(X) > c_{V2}(X)$ and $c_{L2}(C) < c_{V2}(C)$;
- (iv) passing the aqueous stream S_{V2} obtained from the separation unit U_{S1} according to (iii.2) to a water separation unit U_{WS2} .

Regarding the temperature T_{L0} of the stream S_{L0} provided according to (i), it is preferred that T_{L0} is in the range of from 75 to 120 °C, more preferably in the range of from 80 to 110 °C, more preferably in the range of from 85 to 100 °C. As far as the chemical composition of the stream S_{L0} is concerned, it is preferred that the sum of the concentrations $c_{L0}(C)$ and $c_{L0}(X)$, $c_{L0}(C) + c_{L0}(X)$, is at least 60 weight-%, more preferably in the range of from 60 to 95 weight-%, more preferably in the range of from 70 to 90 weight-%, more preferably in the range of from 80 to 85 weight-%, in each case based on the total weight of the stream S_{L0} . Further in the stream S_{L0} , the weight ratio of the one or more compounds X to monomeric ϵ -caprolactam is preferably in the range of from 50:50 to 5:95. Suitable range include, for example, 50:50 to 40:60, or 45:50 to 35:65, or 40:60 to 30:70, or 35:65 to 25:75, or 30:70 to 20:80, or 25:75 to 15:85, or 20:80 to 10:90, or 15:85 to 5:95. According to the present invention, in particular in case the process of the present invention is carried out as a continuous process, the concentration of X in S_{L0} may change over time, depending on which specific material M is fed into the process. In particular for this scenario, the inventive high boiler separation allows for producing a stream S_{V2} having an essentially constant and very low high boiler concentration $c_{V2}(X)$.

Regarding the chemical nature of the high boiler compounds, a comparatively high uncertainty exists, simply in view of the unpredictable chemical composition of the materials subjected to depolymerization and, finally, high boiler separation according to the present invention.

However, when developing the process of the present invention, numerous elaborate

- 5 experiments were carried out, and it was found that in a majority of situations, the one or more compounds X comprised in the stream S_{L0} preferably comprise at least one of
- at least one aromatic amine which includes at least one of an aromatic monoamine, an aromatic diamine, an aromatic triamine and an aromatic tetramine;
 - at least one aliphatic amine which includes at least one of an aliphatic monoamine, an aliphatic diamine and an aliphatic triamine;
 - 10 - at least one aliphatic amide;
 - at least one aromatic alcohol which includes at least one of an aromatic monool and an aromatic diol;
 - at least one aliphatic alcohol which includes at least one of an aliphatic monool and an aliphatic diol;
 - 15 - at least one aromatic acid;
 - at least one and aliphatic acid;
 - at least one ϵ -caprolactam oligomer;
 - at least other compound selected from the group consisting of one or more cleavage products of dyes such as optionally chlorinated aromatic diamines, one or more water-soluble oligomeric cellulose cleavage products, and one or more water-soluble oligomers of terephthalic acid and hexamethylenediamine.
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Yet further, it was found that

- 25 - the at least one aromatic amine preferably includes one or more of 4,4'-methylenedianiline (MDA), isomers thereof such as 2,4'-methylenedianiline and 2,2'-methylenedianiline, and polymethylen polyphenylen polyamines (pMDA);
- the at least one aliphatic amine and the at least one aliphatic amide preferably include one or more of hexamethylenediamine adipate, 6-aminocaproic acid and oligomers thereof,
- 30 including 6-aminocaproic acid dimer and higher oligomers such as 6-aminocaproic acid trimer, 6-aminocaproic acid tetramer, 6-aminocaproic acid pentamer, 6-aminocaproic acid hexamer, N'-(6-aminohexyl)hexane-1,6-diamine, N-methylhexane-1,6-diamine, 6-amino-hexanamide, derivatives of ϵ -caprolactam other than ϵ -caprolactam oligomers and having a boiling point higher than ϵ -caprolactam such as 1-(6-aminohexyl)azepan-2-one;
- 35 - the at least one aliphatic alcohol preferably includes one or more of butanediol and oligomers thereof, including butanediol dimer and higher oligomers such as butanediol trimer, including polytetrahydrofuran;
- the at least one aromatic acid and the at least one aliphatic acid preferably include one or more of terephthalic acid and adipic acid;
- 40 - the at least one ϵ -caprolactam oligomer preferably includes one or more of ϵ -caprolactam dimer ϵ -caprolactam trimer, ϵ -caprolactam tetramer, ϵ -caprolactam pentamer, and ϵ -caprolactam hexamer.

Depending on the specific steps upstream of the high boiler separation steps according to the present invention, the stream S_{L0} further comprises water. Such water-comprising streams S_{L0} are preferred according to the present invention. Therefore, it is preferred that the stream S_{L0} exhibits a concentration $c_{L0}(W)$ of water and wherein $c_{L0}(W)$ is in the range of from 5 to 40 weight-%, preferably in the range of from 10 to 30 weight-%, more preferably in the range of from 15 to 20 weight-%. For these preferred cases, it is further preferred that from 98 to 100 weight-%, more preferably from 99 to 100 weight-%, more preferably from 99.5 to 100 weight-%, more preferably from 99.9 to 100 weight-% of the stream S_{L0} consist of the one or more compounds X, monomeric ϵ -caprolactam, and water.

In the evaporation unit U_{E1} , the evaporation mixture M_{E1} is prepared from the stream S_{L0} , the mixture having an evaporation temperature T_{E1} at an evaporation pressure p_{E1} with $T_{E1} > T_{L0}$. Preferably, p_{E1} is in the range of from 50 to 200 mbar. Suitable ranges may be, for example, from 50 to 100 mbar or from 100 to 150 mbar or from 150 to 200 mbar. Preferably, the temperature T_{E1} is in the range of from 220 to 330 °C, more preferably in the range of from 240 to 320 °C, more preferably in the range of from 260 to 300 °C. Suitable preferred range may be, for example, from 260 to 270 °C or from 270 to 280 °C or from 280 to 290 °C or from 290 to 300 °C.

As far as the preparation of the mixture M_{E1} in the unit U_{E1} according to (ii.1) is concerned, three alternatives and suitable combinations thereof are preferred.

According to a first alternative, preparing the mixture M_{E1} in the unit U_{E1} according to (ii.1) comprises

(a) heating the stream S_{L0} passed into the unit U_{E1} from the temperature T_{L0} to the evaporation temperature T_{E1} via internal heating means H_{INT} arranged within the unit U_{E1} , thereby obtaining the evaporation mixture M_{E1} .

Regarding this alternative, the temperature increase from T_{L0} to T_{E1} is entirely achieved by unit-internal heating means H_{INT} . If, for example, the unit U_{E1} comprises or is a tank reactor such as a continuous stirred tank reactor, said internal heating means H_{INT} are installed within said reactor, and said the temperature increase is achieved by contacting the mixture in the reactor with said internal heating means, wherein said contacting is preferably carried out under agitating such as stirring the mixture. In particular regarding this alternative, the stream S_{L1} removed from the evaporation unit U_{E1} is not recycled back to the unit U_{E1} , neither in total nor partially.

According to a second alternative, preparing the mixture M_{E1} in the unit U_{E1} according to (ii.1) comprises

(b) passing, in addition to the stream S_{L0} , a stream S_{L11} into the unit U_{E1} , the stream S_{L11} having a temperature T_{L11} with $T_{E1} > T_{L11} > T_{L0}$, admixing the stream S_{L11} and the stream S_{L0} and heating the obtained mixture to the temperature T_{E1} via internal heating means H_{INT} arranged within the unit U_{E1} , thereby obtaining the evaporation mixture M_{E1} , wherein the process further comprises

- (ii.4) dividing the stream S_{L1} removed from the unit U_{E1} according to (ii.3) into at least two part streams comprising the stream S_{L11} and a stream S_{L12} , wherein the stream S_{L11} has the temperature T_{L11} with $T_{L11} = T_{L1}$.

Regarding this alternative, the temperature increase from T_{L0} to T_{E1} is achieved by unit-internal heating means H_{INT} and, additionally, by admixing the stream S_{L0} with a recycle stream S_{L11} having a temperature between T_{L0} and T_{E1} . If, for example, the unit U_{E1} comprises or is a tank reactor such as a continuous stirred tank reactor, said internal heating means H_{INT} are installed within said reactor, and said the temperature increase is achieved, on the one hand, by contacting the mixture in the reactor with said internal heating means, wherein said contacting is preferably carried out under agitating such as stirring the mixture; on the other hand, a stream S_{L11} having the temperature T_{L11} and being a part stream of the stream S_{L1} removed from the unit U_{E1} is fed back to unit U_{E1} . In particular regarding this alternative, the stream S_{L11} is not heated by any unit-external heating means prior to being fed back to the unit U_{E1} .

According to a third alternative, preparing the mixture M_{E1} in the unit U_{E1} according to (ii.1) comprises

- (c) passing, in addition to the stream S_{L0} , a stream S_{L11H} into the unit U_{E1} , the stream S_{L11H} having a temperature T_{L11H} with $T_{L11H} > T_{E1}$, and admixing the stream S_{L0} and the stream S_{L11H} , thereby obtaining the evaporation mixture M_{E1} , wherein the process further comprises
- (ii.4) dividing the stream S_{L1} removed from the unit U_{E1} according to (ii.3) into at least two part streams comprising a stream S_{L11} and a stream S_{L12} , wherein the stream S_{L11} has a temperature T_{L11} with $T_{L11} = T_{L1}$;
- (ii.5) subjecting the stream S_{L11} obtained according to (ii.4) to heating via external heating means H_{EXT} arranged outside the unit U_{E1} , obtaining the stream S_{L11H} having the temperature T_{L11H} .

Regarding this alternative, the temperature increase from T_{L0} to T_{E1} is achieved entirely by unit-external heating means H_{EXT} , and no unit-internal heating means H_{INT} are installed. In particular regarding this alternative, the stream S_{L11} is heated by unit-external heating means H_{EXT} prior to being fed back to the unit U_{E1} . Further regarding this alternative, it is preferred that $T_{L11H} \geq (T_{E1} + 10 \text{ K})$, more preferably $T_{L11H} \geq (T_{E1} + 20 \text{ K})$, more preferably $T_{L11H} \geq (T_{E1} + 30 \text{ K})$.

Further alternatives comprise suitable combinations of these alternatives, preferably a combination of the second and the third alternative according to which a part stream S_{L11} is heated by unit-external heating means H_{EXT} prior to being fed back into the unit U_{E1} , wherein in the unit U_{E1} , unit-internal heating means H_{INT} are installed. In this case, the temperature increase from T_{L0} to T_{E1} is achieved by both the unit-external heating means H_{EXT} and the unit-internal heating means H_{INT} .

The term "part stream" S_{L11} as used in this context of the present invention refers to a stream which is obtained by dividing the stream S_{L1} into two or more streams, one of said streams being the stream S_{L11} , wherein from dividing the stream, the obtained (part) streams have the same chemical composition and the same physical parameters as the stream S_{L1} .

Generally, it is preferred that preparing the mixture M_{E1} comprises agitating, preferably mechanical agitating, more preferably stirring. Therefore, the unit U_{E1} preferably comprises a stirred reactor, more preferably a stirred tank reactor, more preferably a continuous stirred tank reactor.

Regarding providing the stream S_{L0} according to (i), it is preferred that it is obtained from the depolymerization of a material M which comprises polyamide 6. More preferably, it is obtained from the hydrolytic depolymerization of a material M which comprises polyamide 6. More preferably, it is obtained from the hydrolytic depolymerization of a material M which comprises polyamide 6 wherein for depolymerization purposes, no polyamide 6 depolymerization catalyst such as a mineral acid and/or a zinc salt such as zinc chloride, zinc acetate or zinc triflate is used for preparing or is contained in the depolymerisation mixture to be subjected to depolymerisation conditions.

More preferably, providing the stream S_{L0} according to (i) comprises

- (i.1) providing a stream S_M comprising a solid material M comprising polyamide 6;
- (i.2) preparing an aqueous depolymerization mixture based on S_M ;
- (i.3) subjecting the depolymerization mixture prepared according to (i.2) to polyamide 6 depolymerization conditions in a reaction unit U_R , obtaining a liquid aqueous stream S_R comprising ϵ -caprolactam dissolved in water at a concentration c_{SR} , the stream S_R further comprising one or more impurities;
- (i.4) passing the liquid aqueous stream S_R into an evaporation unit U_E , obtaining from S_R 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_R one or more aqueous vapor streams S_V ;
- (i.5) passing the aqueous stream S_L into a heat-consuming purification unit U_{P1} , obtaining from S_L the stream S_{L0} and further obtaining from S_L one or more aqueous streams S_{RW} , wherein at least part of the heat consumed in U_{P1} 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} ;
- (i.6) optionally or preferably recycling at least one stream S_{VW} at least partially to the reaction unit U_R and at least one stream S_{RW} at least partially to the reaction unit U_R .

Also more preferably, the stream S_{L0} provided according to (i) is obtainable or obtained by a method comprising

- (i.1) providing a stream S_M comprising a solid material M comprising polyamide 6;
- (i.2) preparing an aqueous depolymerization mixture based on S_M ;
- (i.3) subjecting the depolymerization mixture prepared according to (i.2) to polyamide 6 depolymerization conditions in a reaction unit U_R , obtaining a liquid aqueous stream S_R comprising ϵ -caprolactam dissolved in water at a concentration c_{SR} , the stream S_R further comprising one or more impurities;

- (i.4) passing the liquid aqueous stream S_R into an evaporation unit U_E , obtaining from S_R 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_R one or more aqueous vapor streams S_V ;
- 5 (i.5) passing the aqueous stream S_L into a heat-consuming purification unit U_{P1} , obtaining from S_L the stream S_{L0} and further obtaining from S_L one or more aqueous streams S_{RW} , wherein at least part of the heat consumed in U_{P1} 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} ;
- 10 (i.6) optionally or preferably recycling at least one stream S_{VW} at least partially to the reaction unit U_R and at least one stream S_{RW} at least partially to the reaction unit U_R .

The solid material M preferably comprises, more preferably consists of, waste material, wherein said waste material more preferably comprises, more preferably consists of, one or more of at least one textile waste material and at least one engineering plastics waste material, more

15 preferably comprises, more preferably consists of at least one textile waste material. Preferably from 10 to 99 weight-%, more preferably from 30 to 98.5 weight-%, more preferably from 50 to 98 weight-%, more preferably from 80 to 98 weight-%, of the solid material M consist of the polyamide 6. Preferably, in addition to polyamide 6, the solid material M comprises one or more further organic polymeric compounds, more preferably including, but not limited to, one or more

20 of at least one elastanes, at least one polyethylene terephthalate, at least one polytetrahydrofuran, at least one polyamide 6.6, at least one polyurethane, at least one polyester, at least one cellulose material, and at least one rubber material comprising one or more of at least one natural rubber material and at least one synthetic rubber material.

25 Prior to being provided to the process of the present invention, the collected textile waste material can be suitably sorted. In this regard, it is possible to spread the collected textile waste material on a conveyor, which spreading can be carried out either manually and/or mechanically. Thereafter, the respectively spread textile waste material is subjected to sorting, either by composition and/or by color. Sorting can be carried out either manually and/or

30 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 textile 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

35 current separating means. After said sorting, the respectively obtained textile waste material can be subjected to a further treatment, such as cutting and/or milling.

Generally, the solid material M can be provided according to any suitable method. Preferably according to the present invention, providing the solid material M comprises providing the solid

40 material M in a delivering unit U_{MD} , wherein U_{MD} preferably comprises one or more of at least one big bag station and at least one a bulk container station; passing the provided solid material M via a first connecting line from the unit U_{MD} to a material collecting unit U_{MC} , preferably a collecting drum, wherein the first connecting line preferably comprises one or more of at least

one material receiving and discharge unit U_{MRD} , at least one first material feeding unit U_{FMF} , and at least one first particle separation unit U_{FMPS} ; passing the solid material M from the unit U_{MC} via a second connecting line to the unit U_M , wherein the second connecting line preferably comprises one or more of at least one second material feeding unit U_{SMF} , at least one second particle separation unit U_{SMPS} , and at least one metal detector.

Preferably, the solid material M is provided in the form of granules, wherein the particle size distribution of said granules 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 0.1 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 0.2 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 0.3 to 30 mm and a D90 value of the particle length in the range of from 0.8 to 30 mm.

Generally, the aqueous depolymerisation mixture can be prepared according to any method. Preferably, preparing the aqueous depolymerization mixture according to comprises melting in a melting unit U_M the solid material M , obtaining the liquid stream S_M having a temperature T_{SM} at a pressure p_{SM} ; admixing in a pre-reaction unit U_{PR} the stream S_M with an aqueous stream S_W having a temperature T_{SW} at a pressure p_{SW} , obtaining a liquid reaction feed stream S_F having a temperature T_{SF} at a pressure p_{SF} ; feeding the stream S_F obtained according to (i.3.2) as the depolymerization mixture into the chemical reaction unit U_R . As far as this process design is concerned, it is preferred that

$$0.8 \leq T_{SF}/T_D \leq 1.05 \text{ and } 0.9 \leq p_{SF}/p_D \leq 1.05;$$

$$0.6 \leq T_{SM}/T_{SF} \leq 1.2 \text{ and } 0.9 \leq p_{SM}/p_{SF} \leq 1.05; \text{ and}$$

$$0.8 \leq T_{SW}/T_{SF} \leq 1.2 \text{ and } 0.9 \leq p_{SW}/p_{SF} \leq 1.05.$$

The pre-reaction unit U_{PR} preferably comprises, more preferably consists of, a mixing unit, preferably a static mixing unit, and wherein the melting unit U_M comprises, preferably consists of an extruder, preferably a single-screw extruder or a twin-screw extruder. Further, it is preferred that S_W and S_M are admixed in U_{PR} 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 in S_M .

As far as the hydrolytic depolymerization according to the present invention is concerned, it is preferred that the depolymerization pressure p_D in the unit U_R is 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; and the depolymerisation temperature T_D in the unit U_R is in the range of from 230 to 335 °C, more preferably in the range of from 250 to 320 °C, more preferably in the range of from 270 to 310 °C.

- Preferably, 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. If $z > 1$, is preferred that at least 2 reactors R_i , more preferably all 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 $i < z$;
 - the aqueous liquid stream S_z containing ϵ -caprolactam dissolved in water is removed from the reactor R_z as the stream S_R ;
- 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 from 270 to 310 °C and p_{Di} is in the range of from 40 to 110 bar. For $z > 1$, it is preferred that 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. More preferably, at least 1, preferably all z reactors R_i , are continuous stirred tank reactors (CSTR). Preferably, every continuous stirred tank reactor R_i has, independently from each other, from 2 to 6 compartments, more 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 one flow-through opening. Preferably at least one compartment comprised in a reactor R_i comprises at least one agitator, wherein more 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, and the process comprises agitating the depolymerization mixture in a given compartment for at least part of the time during subjecting to depolymerization conditions in said compartment. Preferably, the polyamide 6 depolymerization conditions further comprise a total residence time t_D of the aqueous depolymerization mixture in the unit U_R , preferably in the z reactors R_i , more preferably in the z continuous 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, the residence time of an aqueous depolymerization mixture in a reactor R_i is t_{Di} and $0.90 \leq (t_{Di} / t_{Di+1}) \leq 1.10$, more preferably $0.95 \leq (t_{Di} / t_{Di+1}) \leq 1.05$.

- If the solid material M comprises one or more elastanes, the aqueous liquid stream S_R obtained from the depolymerization reaction usually contains one or more decomposition products which are formed from the one or more elastanes, for example in the course of the depolymerization reaction in U_R . Additionally or alternatively, one or more decomposition products from the one or more elastanes may also be formed in the melting unit U_M which is described above. By way of example, said one or more decomposition products from the one or more elastanes preferably

include at least one of aniline, butanediol, butanediol oligomers including, for example, butanediol dimer and butanediol trimer, and 4,4'-methylenedianiline (MDA) and isomers thereof such as 2,4'-methylenedianiline and 2,2'-methylenedianiline.

- 5 According to the present invention, it is preferred that the purification unit U_{P1} according to (i.5) comprises a heat-consuming water separation unit U_{WS1} , wherein the process further process comprises feeding the stream S_L to U_{WS1} , obtaining from U_{WS1} the stream S_{L0} . While not being restricted to any specific purification units, it is preferred according to the present invention that U_{WS1} comprises, preferably is an evaporation unit, preferably comprising a film evaporator, more
10 preferably a falling film evaporator, wherein said film evaporator is more preferably equipped with heating means to provide heat for evaporation. Optionally, the unit U_{WS1} may comprise two or more evaporation sub-units, preferably two or more serially coupled evaporation sub-units.

- It is further preferred that from said water separation unit U_{WS1} , not only the stream S_{L0} is
15 obtained which is passed as educt stream to the evaporation unit U_{E1} , but also an aqueous stream S_A , preferably as an at least partially liquid stream, more preferably as a liquid stream. Compared to the stream S_{L0} , an ϵ -caprolactam stream to be subjected to high boiler separation, the stream S_A is an essentially aqueous stream comprising water separated from the stream S_L in U_{WS1} . The stream S_A exhibits a water concentration $c_A(W)$ preferably of at least 95 weight-%,
20 more preferably of at least 98 weight-%, more preferably of at least 99 weight-%, wherein the stream S_A optionally comprises residual amounts ϵ -caprolactam. The stream S_A has a temperature T_A , wherein T_A is preferably in the range of from 15 to 95 °C, more preferably in the range of from 20 to 90 °C, more preferably in the range of from 25 to 85 °C, wherein more preferably $T_A \leq T_{L0}$, more preferably $T_A < T_{L0}$.

- 25 Preferably, prior to being fed into the separation unit U_{S1} , the vapor stream S_{V1} obtained from the evaporation unit U_{E1} is subjected to gas cooling, preferably including a partial condensation. Thus, preferably, (iii.1) comprises subjecting the stream S_{V1} removed from the evaporation unit U_{E1} according to (ii.2), to cooling in cooling unit U_C , obtaining from the unit U_C a cooled stream
30 S_{V1C} , preferably obtaining a cooled and partially condensed stream S_{V1C} , passing the stream S_{V1C} into the separation unit U_{S1} and subjecting the stream S_{V1C} in the separation unit U_{S1} to separation conditions. Among others, it may be preferred that U_C comprises or consists of a scrubber where S_{V1} is admixed with a suitable aqueous stream; generally, such admixing can also be achieved without the use of a scrubber, for example admixing S_{V1} and a suitable
35 aqueous stream by a suitable joining of pipes, or U_C can be just a section of a pipe through which S_{V1} is passed and in which the aqueous stream is sprayed. According to the present invention, it is preferred that said suitable aqueous stream used for cooling and preferred partial condensation of S_{V1} is an aqueous stream which is obtained in the course of the process. In this respect, it is preferred that the stream S_{CW} is a stream obtained from a water separation
40 unit, more preferably from the water separation U_{WS1} upstream of the evaporation unit U_{E1} . Therefore, the water separation unit U_{WS1} not only is the source of the educt stream S_{L0} but also the source of the stream S_{CW} which is used for a preferred downstream treatment of the stream S_{V1} . Therefore, according to (iii.1), it is preferred that the stream S_{V1} is subjected to cooling in

the unit U_C which cooling comprises admixing the stream S_{V1} in the unit U_C with an aqueous stream S_{CW} , preferably with an at least partially liquid aqueous stream S_{CW} , more preferably with a liquid aqueous stream S_{CW} , said aqueous stream S_{CW} having a temperature T_{CW} with $T_{CW} < T_{V1}$, preferably with $T_{CW} \leq T_{L0}$. The respectively obtained stream S_{V1C} has a temperature T_{V1C} preferably in the range of from 160 to 330 °C, more preferably in the range of from 170 to 320 °C, more preferably in the range of from 170 to 300 °C. Preferably from 95 to 100 weight-%, more preferably from 98 to 100 weight-%, more preferably from 99 to 100 weight-% of the stream S_{CW} consist of water. More preferably, the aqueous stream S_{CW} is the aqueous stream S_A as defined above, or a part stream of S_A .

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According to the present invention, it was found that such admixing of S_{V1} with an aqueous stream leads to an absorption of residual amounts of high boilers in S_{V1} which are then suitably separated from ϵ -caprolactam in U_{S1} .

15 According to the present invention, the separation unit U_{S1} is a heat-consuming unit, wherein at least part of the heat consumed in U_{S1} may be provided by at least one of the one or more streams S_V according to (i.4) as defined in embodiment 15, thereby obtaining from the at least one stream S_V at least one at least partially condensed aqueous stream S_{VW} . Preferably, the separation unit U_{S1} comprises, preferably consists of, a droplet separator, preferably selected
20 from the group consisting of a hydrocyclone, a demister plate, and an absorption tower, more preferably a hydrocyclone.

Depending on the specific chemical composition of the stream S_{L2} which is obtained from the separation unit U_{S1} , which composition in turn may depend on the chemical composition of the stream S_{L0} and, therefore, preferably in turn from the chemical composition of the waste
25 material M as defined above, it may be preferred to recycle at least a part of said stream S_{L2} to high boiler separation in U_{E1} . Therefore, the present invention preferably further comprises passing at least a part of the stream S_{L2} removed from the unit U_{S1} according to (iii.3) as educt stream S_{L21} in addition to the stream S_{L0} , into the unit U_{E1} .

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Yet further, again depending on the chemical composition of the stream S_{L2} , it may be preferred to subject at least a part of the stream S_{L2} to a further separation stage where residual amounts of caprolactam are suitably separated. Therefore, the present invention also relates to a process which further comprises passing at least a part of the stream S_{L2} removed from the unit
35 U_{S1} according to (iii.3) as stream S_{L22} into a separation unit U_{S2} , obtaining from the unit a vapor stream S_{VL22} and a liquid stream S_{LL22} , wherein the vapor stream S_{VL22} exhibits a total concentration $c_{VL22}(X)$ of one or more compounds X and a concentration $c_{VL22}(C)$ of monomeric ϵ -caprolactam and wherein the liquid stream S_{LL22} exhibits a total concentration $c_{LL22}(X)$ of one or more compounds X and a concentration $c_{LL22}(C)$ of monomeric ϵ -caprolactam, with
40 $c_{LL22}(X) > c_{VL22}(X)$ and $c_{LL22}(C) < c_{VL22}(C)$. In this respect, it is more preferred that the process still further comprises passing the aqueous stream S_{VL22} obtained from the separation unit U_{S2} to the water separation unit U_{WS2} , optionally after admixing with the stream S_{V2} . The design of the unit U_{S2} is not subject to specific restrictions, and a drum is a possibly preferred design.

Depending on the chemical composition of the stream S_{L1} , it is further possible according to the present invention that at least a part thereof is passed to a further separation stage. In this respect, it is preferred that the process of the present invention further comprises passing at least a part of the stream S_{L1} removed from the unit U_{E1} according to (ii.3) as stream S_{L12} into a separation unit U_{S3} , obtaining from the unit a vapor stream S_{VL12} and a liquid stream S_{LL12} , wherein the vapor stream S_{VL12} exhibits a total concentration $c_{VL12}(X)$ of one or more compounds X and a concentration $c_{VL12}(C)$ of monomeric ϵ -caprolactam and wherein the liquid stream S_{LL12} exhibits a total concentration $c_{LL12}(X)$ of one or more compounds X and a concentration $c_{LL12}(C)$ of monomeric ϵ -caprolactam, with $c_{LL12}(X) > c_{VL12}(X)$ and $c_{LL12}(C) < c_{VL12}(C)$. In case at least one of the one or more compounds X comprised in the stream S_{LL12} is an organic polymeric compound, the process may preferably further comprise passing at least a part of the stream S_{LL12} to a suitable depolymerization unit. With regard to the stream S_{VL12} , it may be preferred to pass at least a part thereof as educt stream in addition to the stream S_{V1} into the cooling unit U_C as defined above. While there are no specific restrictions with regard to the design of the separation unit U_{S3} , it may be preferred that it comprises or consists of a thin film evaporator.

Generally according to the present invention, it may be preferred to passing at least a part of the stream S_{L12} to a suitable depolymerization unit in case at least one of the one or more compounds X comprised in the stream S_{L12} is an organic polymeric compound, the process further comprising passing at least a part of the stream S_{L12} to a depolymerization unit.

According to the present invention, it is conceivable that downstream of the evaporation unit U_{E1} or, if realized, downstream of the separation unit U_{S2} , a part of the stream S_{L1} , such as at least part of the stream S_{L12} , and/or at least a part of the stream S_{LL12} is subjected to suitable cooling, for example in a belt cooler like a steel belt cooler. After cooling, it may be preferred either to discard the cooled material and/or to subject it to a suitable further use.

Regarding the water separation unit U_{WS2} according to (iv), it is preferred that it comprises, preferably is a heat-consuming unit, wherein, more preferably, at least part of the heat consumed in U_{WS2} is provided by at least one of the one or more streams S_V according to (i.4) as defined hereinabove, thereby obtaining from the at least one stream S_V at least one at least partially condensed aqueous stream S_{VW} . More preferably, the water separation unit U_{WS2} comprises, more preferably is a distillation column equipped with heating means to provide heat for distillation. Preferably, the process of the present invention therefore further comprises obtaining from the water separation unit U_{WS2} an aqueous vapor stream S_{V3} and a liquid stream S_{L3} , the stream S_{V3} exhibiting a concentration $c_{V3}(W)$ of water and a concentration $c_{V3}(C)$ of monomeric ϵ -caprolactam and the stream S_{L3} exhibiting a concentration $c_{L3}(W)$ of water and a concentration $c_{L3}(C)$ of monomeric ϵ -caprolactam, with $c_{L3}(W) < c_{V1}(W)$ and $c_{L3}(C) > c_{V3}(C)$.

According to the present invention, it is particularly preferred to subject the ϵ -caprolactam stream S_{L3} obtained from the water separation unit U_{WS2} to further purification, in order to

prepare a highly purified ϵ -caprolactam stream S_{CPL} . In this respect, it is further preferred that the process of the present invention further comprises

- (v) passing the stream S_{L3} into a heat-consuming purification unit U_{P2} , obtaining from S_{L3} a stream S_{CPL} exhibiting a concentration $c_{CPL}(C)$ of monomeric ϵ -caprolactam with $c_{CPL}(C) > c_{L3}(C)$, wherein at least part of the heat consumed in U_{P2} is provided by at least one of the one or more streams S_V according to (i.4) as defined above, thereby obtaining from the at least one stream S_V at least one at least partially condensed aqueous stream S_{VW} .
- 10 Preferably, the heat-consuming purification unit U_{P2} comprises one or more of a distillation sub-unit U_{DI} and a crystallization sub-unit U_{CR} , more preferably comprises a distillation sub-unit U_{DI} and a crystallization sub-unit U_{CR} , wherein the stream S_{CPL} is preferably obtained from the crystallization sub-unit U_{CR} which is preferably arranged downstream of the distillation sub-unit U_{DI} . Regarding the sub-unit U_{DI} , it is preferred that it comprises at least one distillation column,
- 15 preferably two or three distillation columns, more preferably two or three serially coupled distillation columns. According to the present invention, it is preferred that at least part of the heat consumed in one or more of said distillations columns is provided by at least one of the streams S_V from which at least one at least partially condensed stream S_{VW} is obtained which is preferably suitably recycled to U_R . More preferably, at least a part of at least one stream S_V is
- 20 passed as heating medium through a heat exchanger of at least one distillation column of U_{DI} , preferably through a heat exchanger of each of the two or three distillation columns of U_{DI} , more preferably through a heat exchanger used for sump evaporation of each of the two or three distillation columns of U_{DI} . Preferably, a stream S_{DI} is obtained from U_{DI} exhibiting a concentration $c_{DI}(C)$ of monomeric ϵ -caprolactam with $c_{DI}(C) > c_{L3}(C)$, more preferably with
- 25 $c_{CPL}(C) > c_{DI}(C) > c_{L3}(C)$. The respectively obtained stream S_{UDI} which is obtained from U_{DI} and which is further purified with respect to ϵ -caprolactam is then preferably passed to the crystallization unit U_{CR} from which the final stream S_{CPL} is obtained. Regarding the specific design of the crystallization unit U_{CR} is concerned, no specific restrictions exists. Preferably, at least part of the heat consumed in U_{CR} is at least partially provided by at least one stream S_V ,
- 30 wherein based on S_V , at least one at least partially condensed stream S_{VW} is obtained which is preferably suitably recycled to U_R .

- According to a further aspect of the present invention, the process as defined above further comprises providing the stream S_{CPL} to a polyamide 6 production unit U_{PP} , wherein the
- 35 polyamide 6 produced in U_{PP} is preferably provided as a feedstock to a textile material producing unit U_{TP} , from which unit U_{TP}
- (A) a textile material M_{TE} is obtained which is brought onto the market, wherein, after the lifetime T_{TE} of said textile material M_{TE} , it is at least partially collected as textile waste material in a textile material collecting unit U_{TC} ;
- 40 (B) remaining material M_{RTE} is obtained as textile waste material;
- wherein at least part of the textile waste material according to (A), or at least part of the textile waste material according to (B), or at least part of the textile waste material according to (A) and

at least part of the textile waste material according to (B) is suitably provided to U_R as defined hereinabove as S_M .

According to a further aspect of the present invention, the process as defined above further comprises providing the stream S_{CPL} to a polyamide 6 production unit U_{PP} , wherein the polyamide 6 produced in U_{PP} is preferably provided as a feedstock to an engineering plastics material producing unit U_{TP} , from which unit U_{TP}

(A) an engineering plastics material M_{EP} is obtained which is brought onto the market, wherein, after the life-time T_{EP} of said engineering plastics material M_{EP} , it is at least partially collected as engineering plastics waste material in an engineering plastics material collecting unit U_{TC} ;

(B) remaining material M_{REP} is obtained as engineering plastics waste material; wherein at least part of the engineering plastics waste material according to (A), or at least part of the engineering plastics waste material according to (B), or at least part of the engineering plastics waste material according to (A) and at least part of the engineering plastics waste material according to (B) is suitably provided to U_R as defined hereinabove as S_M .

The process of the present invention is a continuous process, a semicontinuous process or a batch process.

According to the present invention, and based on the ultimately purified ϵ -caprolactam stream S_{CPL} , a full recycle loop can be realized. In particular, this is due to the excellent color properties and purity of the crystallized ϵ -caprolactam obtained as stream S_{CPL} .

According to this recycle loop, the stream S_{CPL} is preferably passed to a polyamide 6 production unit, wherein the polyamide 6 produced therein is preferably at least partially provided as a feedstock to a textile material producing unit, wherein the textile material produced in said textile material producing unit is preferably brought onto the market, and wherein, after the life-time of said textile material, it is preferably collected as textile waste material in a textile material collecting unit and preferably suitably provided from said textile material collecting unit to U_R as S_M , preferably via a unit U_{MD} as defined herein. Yet further, it is also possible that in the course of producing the textile material in either the textile material producing unit mentioned above and/or in one or more other production units, remaining material which cannot not be used and which comprises polyamide 6, e.g. in the form of textile cuttings, is obtained; such remaining material is also referred to as "textile waste material" in the context of the present invention, and this textile waste material can also be used as the solid material M or as a part of the solid material M and can be provided to the reaction unit U_R preferably via a unit U_{MD} as defined herein.

Further to this recycle loop, the stream S_{CPL} may also be preferably passed to a polyamide 6 production unit, wherein the polyamide 6 produced therein is preferably at least partially provided as a feedstock to an engineering plastics producing unit, wherein the engineering plastics produced in said engineering plastics producing unit is preferably brought onto the

market, and wherein, after the life-time of said engineering plastics material, it is preferably collected as engineering plastics waste material in an engineering plastics collecting unit and preferably suitably provided from said engineering plastics collecting unit to U_R as S_M , preferably via a unit U_{MD} as defined herein. Yet further, it is also possible that in the course of producing the engineering plastics in either the engineering plastics producing unit mentioned above and/or in one or more other production units, remaining material which cannot not be used and which comprises polyamide 6 is obtained; such remaining material is also referred to as “engineering plastics waste material” in the context of the present invention, and this engineering plastics waste material can also be used as the solid material M or as a part of the solid material M and can be provided to the reaction unit U_R preferably via a unit U_{MD} as defined herein.

According to a further aspect, the present invention also relates to crystallized ϵ -caprolactam, i.e. the stream S_{CPL} as such, obtainable or obtained by a process as described above.

Preferably, said crystallized ϵ -caprolactam exhibits an APHA color (sometimes also referred to as Hazen), determined as described Reference Example 1, of at most 5, preferably of at most 4, more preferably of at most 3, more preferably of at most 2, more preferably of at most 1.5, more preferably of at most 1.

Preferably, said crystallized ϵ -caprolactam exhibits a purity, determined as described in Reference Example 2, of at least 99.8 weight-%, preferably of at least 99.9 weight-%, more preferably of at least 99.95 weight-%, based on the total weight of S_{CPL} .

It is preferred that the crystallized ϵ -caprolactam obtainable or obtained by the process of the present invention exhibits

- an ϵ -caprolactam oligomer content in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm; and/or
- a 6-aminocaproic acid content in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm.

Furthermore, it is preferred that the crystallized ϵ -caprolactam obtainable or obtained by the process of the present invention exhibits

- a triisopropyl borate content in the range of from 0 to 100 weight-ppm, more preferably in the range of from 0 to 50 weight-ppm, more preferably in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm.

In particular in case the solid material M provided according to (i) comprises one or more elastanes, it is preferred that the crystallized ϵ -caprolactam obtainable or obtained by the process of the present invention exhibits

- a polytetrahydrofuran content in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm; and/or
- an aniline content in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm; and/or
- a methylene diphenyl diamine (MDA), isomers and oligomers content in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm; and/or
- a butanediol content in the range of from 0 to 500 weight-ppm, more preferably in the range of from 0 to 300 weight-ppm, more preferably in the range of from 0 to 100 weight-ppm, more preferably in the range of from 0 to 50 weight-ppm, more preferably in the range of from 0 to 10 weight-ppm; and/or
- an ethylene glycol content in the range of from 0 to 500 weight-ppm, more preferably in the range of from 0 to 300 weight-ppm, more preferably in the range of from 0 to 100 weight-ppm, more preferably in the range of from 0 to 50 weight-ppm, more preferably in the range of from 0 to 10 weight-ppm.

In this context of the present invention,

- the term “ ϵ -caprolactam oligomer” encompasses ϵ -caprolactam dimer and higher oligomers, such as ϵ -caprolactam trimer, ϵ -caprolactam tetramer, ϵ -caprolactam pentamer, ϵ -caprolactam hexamer;
- the term “6-aminocaproic acid” encompasses 6-aminocaproic and oligomers thereof, including 6-aminocaproic acid dimer and higher oligomers such as 6-aminocaproic acid trimer, 6-aminocaproic acid tetramer, 6-aminocaproic acid pentamer, 6-aminocaproic acid hexamer;
- the term “aniline” encompasses aniline as such and further encompasses derivatives thereof, such as aniline containing one or more methyl groups, and/or one or more halogen residues, and/or one or more additional amino groups, and/or one or more benzyl groups, wherein examples of such aniline derivatives may include N-methyl aniline and aminotoulene. Methylene dianiline as described hereinunder is not an aniline derivative according to the present invention:
- the term “methylene dianiline” encompasses 4,4'-methylenedianiline (MDA) and isomers thereof such as 2,4'-methylenedianiline and 2,2'-methylenedianiline;
- the term “butanediol” encompasses butanediol as such and oligomers thereof, including butanediol dimer and higher oligomers such as butanediol trimer;
- the term “ethylene glycol” encompasses ethylene glycol as such and oligomers thereof, including diethylene glycol and higher oligomers such as triethylene glycol.

In each case, the respective content refers to an individual compound encompassed by the respective general term. For example with respect to the ϵ -caprolactam oligomer content, the term “an ϵ -caprolactam oligomer content in the range of from 0 to 10 weight-ppm” refers to an ϵ -caprolactam dimer content in the range of from 0 to 10 weight-ppm, an ϵ -caprolactam trimer content in the range of from 0 to 10 weight-ppm, an ϵ -caprolactam tetramer content in the range

of from 0 to 10 weight-ppm, an ϵ -caprolactam pentamer content in the range of from 0 to 10 weight-ppm, an ϵ -caprolactam hexamer content in the range of from 0 to 10 weight-ppm, etc.

- According to a further aspect, the present invention also relates to the use of S_{CPL} , obtainable or obtained by a process as described above, for preparing a polymeric material, preferably for preparing polyamide 6, said use preferably further comprising employing said polyamide 6 as a feedstock for preparing one or more of at least one textile material and at least one engineering plastics material, more preferably for preparing at least one textile material.
- According to a further aspect, the present invention also relates to the use of a process as described above for preparing high-purity ϵ -caprolactam from a solid material M, preferably a waste material comprising polyamide 6 and preferably one or more elastanes, said high-purity ϵ -caprolactam preferably exhibiting one or more of the following properties:
- an ϵ -caprolactam oligomer content in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm;
 - a 6-aminocaproic acid content in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm;
 - a triisopropyl borate content in the range of from 0 to 100 weight-ppm, more preferably in the range of from 0 to 50 weight-ppm, more preferably in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm;
 - a polytetrahydrofuran content in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm;
 - an aniline content in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm;
 - a methylenediphenyl diamine (MDA), isomers and oligomers content in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm;
 - a butanediol content in the range of from 0 to 500 weight-ppm, more preferably in the range of from 0 to 300 weight-ppm, more preferably in the range of from 0 to 100 weight-ppm, more preferably in the range of from 0 to 50 weight-ppm, more preferably in the range of from 0 to 10 weight-ppm; and/or
 - an ethylene glycol content in the range of from 0 to 500 weight-ppm, more preferably in the range of from 0 to 300 weight-ppm, more preferably in the range of from 0 to 100 weight-ppm, more preferably in the range of from 0 to 50 weight-ppm, more preferably in the range of from 0 to 10 weight-ppm.
- According to a further aspect, the present invention relates to the use of S_{CPL} , obtainable or obtained by a process as described above, 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 as described above, as a starting material. In this respect, it is preferred that 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.

Preferably, 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 as described above, wherein the at least one further polymeric compound preferably comprises one or more of at least one polyamide 6.6, at least one polyethylene terephthalate, at least one polyurethane, at least one polyester, at least one cellulose material, and at least one rubber material comprising one or more of at least one natural rubber material and at least one synthetic rubber material.

Further preferably, 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;
- 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;
- 5 - 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.

Preferably according to the use or the method mentioned above, 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 as described above, in

10 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 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

15 weight-% or less, more preferably 50 weight-% or less, more preferably 25 weight-% or less, more preferably 10 weight-% or less.

According to another aspect, the present invention relates to a process as defined herein, comprising the step of converting a chemical material obtainable or obtained by the process as defined herein to obtain a product Ω .

20

Preferably, the product Ω is selected from:

- building block or monomer; or
- polymer, preferably polymer A, polymer composition, preferably polymer composition A, or

25 polymer product, preferably polymer product A; or

- industrial use polymer, industrial use surfactant, descaling compound, industrial use biocide, industrial use solvent, industrial use dispersant, composition thereof or formulation thereof; or
- agrochemical composition, agrochemical formulation auxiliary or agrochemically active

30 ingredient; or

- active pharmaceutical ingredient or intermediate thereof, pharmaceutical excipient, animal feed additive, human food additive, dietary supplements, aroma chemical or aroma composition; or
- aqueous polymer dispersion, preferably polyurethane or polyurethane –

35 poly(meth)acrylate hybrid polymer dispersion, emulsion, binder for paper and fiber coatings, UV-curable acrylic polymer for hot melts and coatings polyisocyanates, hyperbranched polyester polyol, polymeric dispersant for inorganic binder compositions, unsaturated polyester polyol or 100% curable composition; or
- cosmetic surfactant, emollient, wax, cosmetic polymer, UV filter, further cosmetic

40 ingredient or composition or formulation thereof; or

- polymer B, polymer composition B, coating composition, other functional composition, foil, molded body, coating or coated substrate.

- Preferably, the content of the chemical material obtainable or obtained by the process as described herein in the product Ω is 1 weight-% or more, preferably 2 weight-% or more, more preferably 5 weight-% or more, more preferably 15 weight-% or more, more 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
- the content of the chemical material obtainable or obtained by the process as described herein in the product Ω is 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; and preferably wherein the content is determined based on identity preservation and/or segregation and/or mass balance and/or book and claim chain of custody models, preferably based on mass balance, preferably the International Sustainability and Carbon Certification (ISCC) standard.
- The publication Prior Art Disclosure; Issue 684; paragraphs [1000] to [8005]; ISSN: 2198-4786; published: February 12, 2024 will be regarded as Reference RF1, which is incorporated herein by reference in its entirety. Preferably, the product Ω referred to in the preceding paragraph is a product as described in Reference RF1; paragraphs [1000] to [8005]. Preferably, the process described herein is further a process for the production of a product, preferably product Ω .
- The converting step to obtain the product Ω preferably comprises one or more step(s) as described below and can be performed by conventional methods well known to a person skilled in the art. The converting step preferably comprises one or more step(s) selected from: recycling, preferably depolymerizing, gasifying, pyrolyzing, and/or steam cracking; and/or purifying, preferably crystallizing, (solvent) extracting, distilling, evaporating, hydrotreating, absorbing, adsorbing and/or subjecting to ion exchanger; and/or assembling, preferably foaming, synthesizing, chemical conversion, chemically transforming, polymerizing and/or compounding; and/or forming, preferably foaming, extruding and/or molding; and/or finishing, preferably coating and/or smoothing.
- In addition, the one or more step(s) are described in detail in Reference RF1; paragraphs [1000] to [8005].
- The term “building block”, as used in the context of the product Ω herein, comprises compounds, which are in a gaseous or liquid state under standard conditions of 0°C and 0.1 MPa. Building blocks are typically used in chemical industry to form secondary products, which provide a higher structural complexity and/or higher molecular weight than the building block on which the secondary product is based. The building block is preferably selected from the group consisting of hydrogen, carbon monoxide, carbon dioxide, ethylene oxide, ethylene glycols, syngas comprising a mixture of hydrogen and carbon monoxide, alkanes, alkenes, alkynes and aromatic compounds. The alkanes, alkenes, alkynes and aromatic compounds comprise in particular 1 to 12 carbon atoms, respectively.

The term “monomer”, as used in the context of the product Ω herein, comprises molecules, which can react with each other to form polymer chains by polymerization. The monomer is preferably selected from the group consisting of (meth)acrylic acid, salts of (meth)acrylic acid; in particular sodium, potassium and zinc salts; (meth)acrolein and (meth)acrylates.

5 (Meth)acrylates comprising 1 to 22 carbon atoms are preferred, in particular comprising 1 to 8 carbon atoms. The terms (meth)acrylic acid, (meth)acrolein or (meth)acrylate relate to acrylic acid, acrolein or acrylate and also to methacrylic acid, methacrolein or methacrylate, where applicable. Further, the monomer can be selected from hexamethylenediamine (HMD) and adipic acid.

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The building block can further be an intermediate compound. The term “intermediate compound”, as used in the context of the product Ω herein, comprises organic reagents, which are applied for formation of compounds with higher molecular complexity. The intermediate compound can be selected for example from the group consisting of phosgene, polyisocyanates and propylene oxide. The polyisocyanates are in particular aromatic di- and polyisocyanates, preferably toluene diisocyanate (TDI) and/or diphenylmethane diisocyanate (MDI).

15

The building block and the monomer and typical converting step(s) to obtain the building block or monomer are described in more detail in paragraphs [1000] to [1012] of Reference RF1.

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The term “polymer A”, as used in the context of the product Ω herein, comprises thermoplastic, e.g., polyamide or thermoplastic polyurethane, thermoset, e.g., polyurethane, elastomer, e.g., polybutadiene, or a copolymer or a mixture thereof and is defined in more detail in paragraphs [2001] to [2007] of Reference RF1.

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The term “polymer composition A”, as used in the context of the product Ω herein, comprises all compositions comprising a polymer as described above and one or more additive(s), e.g. reinforcement, colorant, modifier and/or flame retardant, and is defined in more detail in paragraph [2008] of Reference RF1.

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The term “polymer product A”, as used in the context of the product Ω herein, comprises any product comprising the polymer A and/or polymer composition A as described above and is defined in more detail in paragraphs [2009] and [2010] of Reference RF1.

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The step(s) to obtain the polymer, preferably polymer A, polymer composition, preferably polymer composition A or polymer product, preferably polymer product A is/are described in more detail in paragraph [2011] of Reference RF1.

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The term “industrial use polymer”, as used in the context of the product Ω herein, comprises rheology, polycarboxylate, alkoxylated polyalkylenamine, alkoxylated polyalkylenimine, polyether-based, dye inhibition and soil release cleaning polymers defined in more detail in paragraphs [3035] to [3044] of Reference RF1. The term “industrial use surfactant”, as used in the context of the product Ω herein, comprises non-ionic, anionic and amphoteric industrial use surfactants defined in more detail in paragraphs [3008] to [3034] of Reference RF1. The term

“industrial use descaling compound”, as used in the context of the product Ω herein, comprises non-phosphate based builders (NPB) and phosphonates (CoP) described in more detail in paragraphs [3001] to [3005] of Reference RF1. The term “industrial use biocide”, as used herein, refers to a chemical compound that kills microorganisms or inhibits their growth or reproduction defined in more detail in paragraphs [3006] to [3007] of Reference RF1. The term “industrial use solvent”, as used in the context of the product Ω herein, comprises alkyl amides, alkyl lactamides, alkyl esters, lactate esters, alkyl diester, cyclic alkyl diester, cyclic carbonates, aromatic aldehydes and aromatic esters defined in more detail in paragraphs [3045] to [3055] of Reference RF1. The term “industrial use dispersant”, as used in the context of the product Ω herein, comprises anionic and non-ionic industrial use dispersants defined in more detail in paragraphs [3056] to [3058] of Reference RF1. The term “composition and/or formulation thereof” with reference to the industrial use polymers, industrial use surfactants, descaling compounds and/or industrial use biocides refers to industrial use compositions and/or institutional use products and/or fabric and home care products and/or personal care products defined in more detail in paragraph [3059] of Reference RF1. The converting step(s) to obtain the industrial use polymer, industrial use surfactant, descaling compound and/or industrial use biocide are defined in more detail in paragraph [3060] of Reference RF1. The converting steps to obtain the industrial use composition or formulation of the industrial use polymer, industrial use surfactant, descaling compound and/or industrial use biocide are defined in more detail in paragraph [3061] of Reference RF1.

The term “agrochemical composition”, as used in the context of the product Ω herein, typically relates to a composition comprising an agrochemically active ingredient and at least one agrochemical formulation auxiliary. Examples of agrochemical compositions, active ingredients and auxiliaries are described in more detail in Reference RF1, paragraph [4001].

The agrochemical composition may take the form of any customary formulation. The agrochemical compositions are prepared in a known manner, e.g. described by Mollet and Grubemann, Formulation technology, Wiley VCH, Weinheim, 2001; or Knowles, New developments in crop protection product formulation, Agrow Reports DS243, T&F Informa, London, 2005. The converting step(s) to obtain the agrochemically active ingredients and auxiliaries may be conducted in analogy to the production step(s) of their analogues that are based on petrochemicals or other precursors that are not gained by recycling processes. In addition, conversion to compounds mentioned in sections “Polymer” and “Cosmetic surfactant, emollient, wax, cosmetic polymer, UV filter, further cosmetic ingredient or compositions or formulations thereof” may be performed as described in these sections as well as the respective paragraphs in Reference RF1.

The term active pharmaceutical ingredients and/or intermediates thereof, as used in the context of the product Ω herein, comprises substances that provide pharmacological activity or other direct effect in the diagnosis, cure, mitigation, treatment, or prevention of disease, or to affect the structure or any function of the body. Intermediates thereof are isolated products that are generated during a multi-step route of synthesis of an active pharmaceutical ingredient. The

term pharmaceutical excipients, as used in the context of the product Ω herein, comprises compounds or compound mixtures used in compositions for various pharmaceutical applications, which are not substantially pharmaceutically active on itself. Active pharmaceutical ingredients and/or intermediates thereof and pharmaceutical excipients are defined in more detail in paragraph [5001] of Reference RF1.

The converting step(s) to obtain the active pharmaceutical ingredients and/or intermediates thereof and pharmaceutical excipients may comprise one or more synthesis steps and can be performed by conventional synthesis and techniques well known to a person skilled in the art.

The terms animal feed additives, human food additives, dietary supplements, as used in the context of the product Ω herein, comprises Vitamins, Pro-Vitamins and active metabolites thereof including intermediates and precursors, especially Vitamin A, B, E, D, K and esters thereof, like acetate, propionate, palmitate esters or alcohols thereof like retinol or salts thereof and any combinations thereof; Tetraterpenes, especially isoprenoids like carotenoids and xanthophylls including their intermediates and precursors as well as mixtures and derivatives thereof, especially beta carotene, Canthaxanthin, Citranaxanthin, Astaxanthin, Zeaxanthin, Lutein, Lycopene, Apo-carotenoids, and any combinations thereof; organic acids, especially formic acid, propionic acid and salts thereof, such as sodium, calcium or ammonium salts, and any combinations thereof, such as but not limited to mixtures of formic acid and sodium formate, propionic acid and ammonium propionate, formic acid and propionic acid, formic acid and sodium formate and propionic acid, propionic acid and sodium propionate and formic acid and sodium formate; glycerides of carboxylic acids and short and medium chain fatty acids, conjugated linoleic acids, such as omega-6 fatty acid (C18:2) methyl ester and 1,2-propandiol and beverage stabilizers, such as polyvinylpyrrolidone-polymer or polyvinylimidazole/polyvinylpyrrolidone-copolymer. Animal feed additives, human food additives and dietary supplements are defined in more detail in paragraph [5002] of Reference RF1.

The converting step(s) to obtain the animal feed additives, human food additives, dietary supplements may comprise one or more synthesis steps and can be performed by conventional synthesis and techniques well known to a person skilled in the art.

The terms aroma chemical and aroma composition as used in the context of the product Ω here-in, comprise a volatile organic substance with a molecular weight between 70-250 g/mol comprising a functional group with a carbon skeleton of C5-C16 carbon atoms comprising linear, branched, cyclic, for example with a ring size of C5-C18, bicyclic or tricyclic aliphatic chains and but not necessarily one or more unsaturated structural elements like double bonds, triple bonds, aromatics or heteroaromatics and preferably the one or more additional functional groups are selected from alcohol, ether, ester, ketone, aldehyde, acetal, carboxylic acid, nitrile, thiol, amine. In one aspect, the aroma chemical is a terpene-based aroma chemical, for example selected from monoterpenes and monoterpenoids, sesquiterpenes and sesquiterpenoids, diterpenes, triterpenes or tetraterpenes. Aroma chemicals can be combined

with further aroma chemicals to give an aroma composition. Aroma chemicals and aroma compositions are defined in more detail in paragraph [5003] of Reference RF1.

5 The converting step(s) to obtain the aroma chemical and aroma composition may comprise one or more synthesis steps and can be performed by conventional synthesis and techniques well known to a person skilled in the art.

10 The term “aqueous polymer dispersion”, as used in the context of the product Ω herein, comprises aqueous composition(s) comprising dispersed polymer(s) and is defined in more detail in the section [6001] entitled “aqueous polymer dispersion” of Reference RF1. The dispersed polymer(s) may be selected from acrylic emulsion polymer(s), styrene acrylic emulsion polymer(s), styrene butadiene dispersion(s), aqueous dispersion(s) comprising composite particles, acrylate alkyd hybrid dispersion(s), polyurethane(s) (including UV-curable polyurethanes) and polyurethane - poly(meth)acrylate hybrid polymer(s). The term “emulsion
15 polymer”, as used herein, comprises polymer(s) made by free-radical emulsion polymerization. Aqueous polyurethane dispersion(s) are defined in more detail in the section [6002] entitled “Polyurethane dispersions” of Reference RF1. UV-curable polyurethane(s) is/are defined in more detail in the section [6017] of Reference RF1. Polyurethane - poly(meth)acrylate hybrid polymer(s) is/are defined in more detail in the section [6016] of Reference RF1.

20 The term “polymeric dispersant”, as used in the context of the product Ω herein, comprises preferably polymer(s) comprising polyether side chain, in particular polycarboxylate ether polymer(s) and polycondensation product(s) defined in more detail in paragraph [6020] entitled “Polymeric dispersant” of Reference RF1.

25 The converting (polymerization) step(s) to obtain the aqueous polymer dispersion(s) comprising emulsion polymer(s) is/are defined in more detail in the section [6003] entitled “Emulsion polymerization” of Reference RF1.

30 The converting (polymerization) step(s) to obtain the aqueous polyurethane dispersion(s) is/are defined in more detail in the section [6014] entitled “Process for the preparation of aqueous poly-urethane dispersions” and section [6017]) entitled “Aqueous UV-curable polyurethane dispersions, their preparation and use and compositions containing them” of Reference RF1.

35 Composition(s) and uses of aqueous polymer dispersion(s) and of polymeric dispersant(s) are defined in more detail in the following sections of Reference RF1:
section [6004] entitled “Uses of aqueous polymer dispersions”,
section [6005] entitled “Binders for architectural and construction coatings”
section [6006] entitled “Binders for paper coating”
40 section [6007] entitled “Binders for fiber bonding”
section [6008] entitled “Adhesive polymers and adhesive compositions”
section [6015] entitled “Aqueous polyurethane dispersions suitable for use in coating compositions”

section [6016] entitled "Aqueous polyurethane - poly(meth)acrylate hybride polymer dispersions suitable for use in coating compositions"

section [6017] entitled "Aqueous UV-curable polyurethane dispersions, their preparation and use and compositions containing them"

- 5 section [6018] entitled "Inorganic binder compositions comprising polymeric dispersants and their use" [6019] 100% curable coating compositions

- 10 UV-crosslinkable poly(meth)acrylate(s) and its/their uses are defined in more detail in section [6009] entitled "UV-crosslinkable poly(meth)acrylates for use in UV-curable solvent-free hot melt adhesives and their use for making pressure-sensitive self-adhesive articles" of Reference RF1.

Polyisocyanate(s), composition(s) comprising them and their uses are defined in more detail in section [6010] entitled "Polyisocyanates" of Reference RF1.

- 15 Hyperbranched polyester polyol(s) and its/their uses are defined in more detail in section [6011] entitled "Organic solvent based hyperbranched polyester polyols suitable for use in coating compositions" of Reference RF1. The converting step(s) to obtain the hyperbranched polyester polyols is/are defined in more detail in the section [6012] entitled "Preparation of organic solvent based hyperbranched polyester polyols" of Reference RF1. Coating composition(s) comprising
20 hyperbranched polyester polyol(s), polyisocyanate(s) and additive(s) and substrate(s) coated therewith are defined in more detail in section [6013] entitled "Organic solvent based two component coating compositions comprising hyperbranched polyester polyols and polyisocyanates" of Reference RF1.

- 25 Unsaturated polyester polyol(s), solvent-based coating composition(s) comprising said unsaturated polyester polyol(s) and substrate(s) for coating with said coating composition(s) are defined in more detail in section [6018] entitled "Organic solvent based coating composition comprising unsaturated polyester polyols" of Reference RF1.
100% curable coating composition(s) is/are defined in more detail in section [6019] of
30 Reference RF1.

- Polymeric dispersant(s) for inorganic binder compositions is/are defined in more detail in section [6020] of Reference RF1. The inorganic binder composition(s) comprising the polymeric dispersants and their use are defined in more detail in section [6021] of Reference RF1. The
35 converting step(s) to obtain the polymeric dispersant(s) are defined in more detail in section [6020] of Reference RF1. The term "inorganic binder composition" comprising the polymeric dispersant(s), as used herein, comprises preferably in particular hydraulically setting compositions and compositions comprising calcium sulfate and is defined in more detail in section [6021] of Reference RF1 entitled "Inorganic binder compositions comprising the
40 polymeric dispersant and their use". Specific building material formulation(s) comprising polymeric dispersant(s) or building product(s) produced by a building material formulation comprising a polymeric dispersant are disclosed in more detail in section [6021] of Reference RF1.

- The term “cosmetic surfactant”, as used in the context of the product Ω herein, comprises non-ionic, anionic, cationic and amphoteric surfactants and is defined in more detail in paragraph [7002] of Reference RF1. The term “emollient”, as used in the context of the product Ω herein, refers to a chemical compound used for protecting, moisturizing, and/or lubricating the skin and is defined in more detail in paragraph [7003] of Reference RF1. The term “wax”, as used in the context of the product Ω herein, comprises pearlzers and opacifiers and is defined in more detail in paragraph [7004] of Reference RF1. The term “cosmetic polymer”, as used in the context of the product Ω herein, comprises any polymer that can be used as an ingredient in a cosmetic formulation and is defined in more detail in paragraph [7005] of Reference RF1. The term “UV filter”, as used in the context of the product Ω herein, refers to a chemical compound that blocks or absorbs ultraviolet light and is defined in more detail in paragraph [7006] of Reference RF1. The term “further cosmetic ingredient”, as used in the context of the product Ω herein, comprises any ingredient suitable for making a cosmetic formulation. Several sources disclose cosmetically acceptable ingredients. E. g. the database Cosing on the internet pages of the European Commission discloses cosmetic ingredients and the International Cosmetic Ingredient Dictionary and Handbook, edited by the Personal Care Products Council (PCPC), discloses cosmetic ingredients. The term “composition and/or formulation thereof” with reference to the cosmetic surfactant, emollient, wax, cosmetic polymer, UV filter and/or further cosmetic ingredient refers to personal care and/or cosmetic compositions or formulations defined in more detail in paragraph [7007] of Reference RF1. The converting step(s) to obtain the cosmetic surfactant, emollient, wax, cosmetic polymer, UV filter or further cosmetic ingredient is/are defined in more detail in paragraph [7008] of Reference RF1.
- The terms “polymer B”, “polymer composition B”, “coating composition”, “other functional composition”, “foil”, “molded body”, “coating” and “coated substrate” are well known to the person skilled in the art and are defined in more detail from paragraph [8000] to [8005] of Reference RF1.
- 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 separating one or more organic compounds X from an aqueous liquid stream S_{L0} comprising monomeric ϵ -caprolactam and said one or more compounds X, the process comprising

- (i) providing the stream S_{L0} having a temperature T_{L0} and exhibiting a total concentration $c_{L0}(X)$ of the one or more compounds X and a concentration $c_{L0}(C)$ of monomeric ϵ -caprolactam;
- (ii) producing in an evaporation unit U_{E1} from the stream S_{L0} an aqueous at least partially vaporous stream S_{V1} and a liquid stream S_{L1} , comprising
- 5 (ii.1) passing the stream S_{L0} provided according to (i) into the unit U_{E1} , preparing in the unit U_{E1} from the stream S_{L0} an evaporation mixture M_{E1} having an evaporation temperature T_{E1} at an evaporation pressure p_{E1} with $T_{E1} > T_{L0}$, wherein the one or more organic compounds X have a boiling point T_{BX} and ϵ -caprolactam has a boiling point T_{BC} with $T_{BX} > T_{E1} \geq T_{BC}$ at the evaporation pressure p_{E1} ;
- 10 (ii.2) removing the stream S_{V1} from the evaporation unit U_{E1} , the stream S_{V1} having a temperature T_{V1} with $T_{V1} \leq T_{E1}$ and exhibiting a total concentration $c_{V1}(X)$ of one or more compounds X and a concentration $c_{V1}(C)$ of monomeric ϵ -caprolactam with $c_{V1}(C) > c_{L0}(C)$ and $c_{V1}(X) < c_{L0}(X)$;
- 15 (ii.3) removing the stream S_{L1} from the evaporation unit U_{E1} , the stream S_{L1} having a temperature T_{L1} with $T_{L1} = T_{E1}$ and exhibiting a total concentration $c_{L1}(X)$ of one or more compounds X and a concentration $c_{L1}(C)$ of monomeric ϵ -caprolactam with $c_{L1}(C) < c_{E1}(C)$ and $c_{L1}(X) > c_{L0}(X)$;
- 20 (iii) producing in a separation unit U_{S1} from the stream S_{V1} an aqueous vapor stream S_{V2} and a liquid stream S_{L2} , comprising
- (iii.1) passing the stream S_{V1} removed from the evaporation unit U_{E1} according to (ii.2), optionally after cooling, into the separation unit U_{S1} and subjecting the stream S_{V1} , optionally the stream after cooling, in the separation unit U_{S1} to separation conditions;
- 25 (iii.2) removing the stream S_{V2} from the separation unit U_{S1} , the stream S_{V2} having a temperature T_{V2} with $T_{L0} < T_{V2} \leq T_{V1}$ and exhibiting a total concentration $c_{V2}(X)$ of one or more compounds X and a concentration $c_{V2}(C)$ of monomeric ϵ -caprolactam;
- 30 (iii.3) removing the stream S_{L2} from the separation unit U_{S1} , the stream S_{L2} having a temperature T_{L2} with $T_{L2} = T_{V2}$ and exhibiting a total concentration $c_{L2}(X)$ of one or more compounds X and a concentration $c_{L2}(C)$ of monomeric ϵ -caprolactam with $c_{L2}(X) > c_{V2}(X)$ and $c_{L2}(C) < c_{V2}(C)$;
- 35 (iv) passing the aqueous stream S_{V2} obtained from the separation unit U_{S1} according to (iii.2) to a water separation unit U_{WS2} .
2. The process of embodiment 1, wherein T_{L0} is in the range of from 75 to 120 °C, preferably in the range of from 80 to 110 °C, more preferably in the range of from 85 to 100 °C.
- 40 3. The process of embodiment 1 or 2, wherein $c_{L0}(C) + c_{L0}(X)$ is at least 60 weight-%, preferably in the range of from 60 to 95 weight-%, more preferably in the range of from 70 to 90 weight-%, more preferably in the range of from 80 to 85 weight-%.

4. The process of any one of embodiments 1 to 3, wherein in the stream S_{L0} , the weight ratio of the one or more compounds X to monomeric ϵ -caprolactam is in the range of from 50:50 to 5:95.
5. The process of any one of embodiments 1 to 4, wherein the one or more compounds X comprised in the stream S_{L0} comprise at least one of
- at least one aromatic amine which includes at least one of an aromatic monoamine, an aromatic diamine, an aromatic triamine and an aromatic tetramine;
 - at least one aliphatic amine which includes at least one of an aliphatic monoamine, an aliphatic diamine and an aliphatic triamine;
 - at least one aliphatic amide;
 - at least one aromatic alcohol which includes at least one of an aromatic monool and an aromatic diol;
 - at least one aliphatic alcohol which includes at least one of an aliphatic monool and an aliphatic diol;
 - at least one aromatic acid;
 - at least one and aliphatic acid;
 - at least one ϵ -caprolactam oligomer;
 - at least other compound selected from the group consisting of one or more cleavage products of dyes such as optionally chlorinated aromatic diamines, one or more water-soluble oligomeric cellulose cleavage products, and one or more water-soluble oligomers of terephthalic acid and hexamethylenediamine.
6. The process of embodiment 5, wherein
- the at least one aromatic amine includes one or more of 4,4'-methylenedianiline (MDA), isomers thereof such as 2,4'-methylenedianiline and 2,2'-methylenedianiline, and polymethylen polyphenylen polyamines (pMDA);
 - the at least one aliphatic amine and the at least one aliphatic amide include one or more of hexamethylenediamine adipate, 6-aminocaproic acid and oligomers thereof, including 6-aminocaproic acid dimer and higher oligomers such as 6-aminocaproic acid trimer, 6-aminocaproic acid tetramer, 6-aminocaproic acid pentamer, 6-aminocaproic acid hexamer, N'-(6-aminohexyl)hexane-1,6-diamine, N-methyl-hexane-1,6-diamine, 6-aminohexanamide, derivatives of ϵ -caprolactam other than ϵ -caprolactam oligomers and having a boiling point higher than ϵ -caprolactam such as 1-(6-aminohexyl)azepan-2-one;
 - the at least one aliphatic alcohol includes one or more of butanediol and oligomers thereof, including butanediol dimer and higher oligomers such as butanediol trimer, including polytetrahydrofuran;
 - the at least one aromatic acid and the at least one aliphatic acid include one or more of terephthalic acid and adipic acid;
 - the at least one ϵ -caprolactam oligomer includes one or more of ϵ -caprolactam dimer ϵ -caprolactam trimer, ϵ -caprolactam tetramer, ϵ -caprolactam pentamer, and ϵ -caprolactam hexamer.

7. The process of any one of embodiments 1 to 6, wherein the stream S_{L0} exhibits a concentration $c_{L0}(W)$ of water and wherein $c_{L0}(W)$ is in the range of from 5 to 40 weight-%, preferably in the range of from 10 to 30 weight-%, more preferably in the range of from 15 to 20 weight-%.
8. The process of any one of embodiments 1 to 7, wherein from 98 to 100 weight-%, preferably from 99 to 100 weight-%, more preferably from 99.5 to 100 weight-%, more preferably from 99.9 to 100 weight-% of S_{L0} consist of the one or more compounds X, monomeric ϵ -caprolactam, and water.
9. The process of any one of embodiments 1 to 8, wherein p_{E1} is in the range of from 50 to 200 mbar.
10. The process of any one of embodiments 1 to 9, preferably of embodiment 9, wherein T_{E1} is in the range of from 220 to 330 °C, preferably in the range of from 240 to 320 °C, more preferably in the range of from 260 to 300 °C.
11. The process of any one of embodiments 1 to 10, wherein preparing the mixture M_{E1} in the unit U_{E1} according to (ii.1) comprises
- (a) heating the stream S_{L0} passed into the unit U_{E1} from the temperature T_{L0} to the evaporation temperature T_{E1} via internal heating means H_{INT} arranged within the unit U_{E1} , thereby obtaining the evaporation mixture M_{E1} ;
- or comprises
- (b) passing, in addition to the stream S_{L0} , a stream S_{L11} into the unit U_{E1} , the stream S_{L11} having a temperature T_{L11} with $T_{E1} > T_{L11} > T_{L0}$, admixing the stream S_{L11} and the stream S_{L0} and heating the obtained mixture to the temperature T_{E1} via internal heating means H_{INT} arranged within the unit U_{E1} , thereby obtaining the evaporation mixture M_{E1} , wherein the process further comprises
- (ii.4) dividing the stream S_{L1} removed from the unit U_{E1} according to (ii.3) into at least two part streams comprising the stream S_{L11} and a stream S_{L12} , wherein the stream S_{L11} has the temperature T_{L11} with $T_{L11} = T_{L1}$;
- or comprises
- (c) passing, in addition to the stream S_{L0} , a stream S_{L11H} into the unit U_{E1} , the stream S_{L11H} having a temperature T_{L11H} with $T_{L11H} > T_{E1}$, and admixing the stream S_{L0} and the stream S_{L11H} , thereby obtaining the evaporation mixture M_{E1} , wherein the process further comprises
- (ii.4) dividing the stream S_{L1} removed from the unit U_{E1} according to (ii.3) into at least two part streams comprising a stream S_{L11} and a stream S_{L12} , wherein the stream S_{L11} has a temperature T_{L11} with $T_{L11} = T_{L1}$;
- (ii.5) subjecting the stream S_{L11} obtained according to (ii.4) to heating via external heating means H_{EXT} arranged outside the unit U_{E1} , obtaining the stream S_{L11H} having the temperature T_{L11H} .

12. The process of embodiment 11, wherein according to (c), wherein $T_{L11H} \geq (T_{E1} + 10 \text{ K})$, preferably $T_{L11H} \geq (T_{E1} + 20 \text{ K})$, more preferably $T_{L11H} \geq (T_{E1} + 30 \text{ K})$.
- 5 13. The process of any one of embodiments 1 to 12, wherein preparing the mixture M_{E1} comprises stirring.
14. The process of any one of embodiments 1 to 13, wherein the unit U_{E1} comprises a stirred reactor, preferably a stirred tank reactor, more preferably a continuous stirred tank reactor.
- 10 15. The process of any one of embodiments 1 to 14, wherein providing the stream S_{L0} according to (i) comprises, and/or wherein the stream S_{L0} is obtainable or obtained by a method comprising
- 15 (i.1) providing a stream S_M comprising a solid material M comprising polyamide 6;
- (i.2) preparing an aqueous depolymerization mixture based on S_M ;
- (i.3) subjecting the depolymerization mixture prepared according to (i.2) to polyamide 6 depolymerization conditions in a reaction unit U_R , obtaining a liquid aqueous stream S_R comprising ϵ -caprolactam dissolved in water at a concentration c_{SR} , the stream
- 20 S_R further comprising one or more impurities;
- (i.4) passing the liquid aqueous stream S_R into an evaporation unit U_E , obtaining from S_R 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_R one or more aqueous vapor streams S_V ;
- 25 (i.5) passing the aqueous stream S_L into a heat-consuming purification unit U_{P1} , obtaining from S_L the stream S_{L0} and further obtaining from S_L one or more aqueous streams S_{RW} , wherein at least part of the heat consumed in U_{P1} 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} ;
- 30 (i.6) preferably recycling at least one stream S_{VW} at least partially to the reaction unit U_R and at least one stream S_{RW} at least partially to the reaction unit U_R ;
- wherein the solid material M preferably comprises, more preferably consists of, waste material, wherein said waste material more preferably comprises, more preferably consists of, one or more of at least one textile waste material and at least one engineering plastics waste material, more preferably comprises, more preferably consists of at least one textile waste material;
- 35 wherein preferably from 10 to 99 weight-%, more preferably from 30 to 98.5 weight-%, more preferably from 50 to 98 weight-%, more preferably from 80 to 98 weight-%, of the solid material M consist of the polyamide;
- 40 wherein preferably, in addition to polyamide 6, the solid material M comprises one or more further organic polymeric compounds, more preferably including, but not limited to, one or more of at least one elastanes, at least one polyethylene terephthalate, at least one polytetrahydrofuran, at least one polyamide 6.6, at least one polyurethane, at least one

polyester, at least one cellulose material, and at least one rubber material comprising one or more of at least one natural rubber material and at least one synthetic rubber material.

- 5 16. The process of embodiment 15, wherein the purification unit U_{P1} according to (i.5) comprises a heat-consuming water separation unit U_{WS1} , the process comprising feeding the stream S_L to U_{WS1} , obtaining from U_{WS1} the stream S_{L0} .
- 10 17. The process of embodiments 16, wherein in addition to the S_{L0} , an aqueous stream S_A is obtained from U_{WS1} , wherein the stream S_A is preferably an at least partially liquid stream, more preferably a liquid stream.
- 15 18. The process of embodiment 17, wherein the stream S_A exhibits a water concentration $c_A(W)$ of at least 95 weight-%, preferably of at least 98 weight-%, more preferably of at least 99 weight-%, wherein the stream S_A optionally comprises ϵ -caprolactam.
- 20 19. The process of embodiment 17 or 18, wherein the stream S_A has a temperature T_A , wherein T_A is in the range of from 15 to 95 °C, preferably in the range of from 20 to 90 °C, more preferably in the range of from 25 to 85 °C, wherein more preferably $T_A \leq T_{L0}$, more preferably $T_A < T_{L0}$.
- 25 20. The process of any one of embodiments 1 to 19, wherein (iii.1) comprises (iii.1) subjecting the stream S_{V1} removed from the evaporation unit U_{E1} according to (ii.2), to cooling in cooling unit U_C , obtaining from the unit U_C a cooled stream S_{V1C} , preferably obtaining a cooled and partially condensed stream S_{V1C} , passing the stream S_{V1C} into the separation unit U_{S1} and subjecting the stream S_{V1C} in the separation unit U_{S1} to separation conditions.
- 30 21. The process of embodiment 20, wherein according to (iii.1), subjecting the stream S_{V1} to cooling in the unit U_C comprises admixing the stream S_{V1} in the unit U_C with an aqueous stream S_{CW} , preferably with an at least partially liquid aqueous stream S_{CW} , more preferably with a liquid aqueous stream S_{CW} , said aqueous stream S_{CW} having a temperature T_{CW} with $T_{CW} < T_{V1}$, preferably with $T_{CW} \leq T_{L0}$.
- 35 22. The process of embodiment 20 or 21, wherein the stream S_{V1C} has a temperature T_{V1C} in the range of from 160 to 330 °C, preferably in the range of from 170 to 320 °C, more preferably in the range of from 170 to 300 °C.
- 40 23. The process of embodiment 21 or 22, wherein from 95 to 100 weight-%, preferably from 98 to 100 weight-%, more preferably from 99 to 100 weight-% of the stream S_{CW} consist of water.
24. The process of any one of embodiments 21 to 23, wherein the aqueous stream S_{CW} is the aqueous stream S_A as defined in any one of embodiments 17 to 19.

25. The process of any one of embodiments 20 to 24, wherein the cooling unit U_C comprises a scrubber.
- 5 26. The process of any one of embodiments 1 to 25, wherein the separation unit U_{S1} is a heat-consuming unit, wherein at least part of the heat consumed in U_{S1} is provided by at least one of the one or more streams S_V according to (i.4) as defined in embodiment 15, thereby obtaining from the at least one stream S_V at least one at least partially condensed aqueous stream S_{WW} .
- 10 27. The process of any one of embodiments 1 to 26, wherein the separation unit U_{S1} comprises, preferably consists of, a droplet separator, preferably selected from the group consisting of a hydrocyclone, a demister plate, and an absorption tower, more preferably a hydrocyclone.
- 15 28. The process of any one of embodiments 1 to 27, further comprising passing at least a part of the stream S_{L2} removed from the unit U_{S1} according to (iii.3) as educt stream S_{L21} in addition to the stream S_{L0} , into the unit U_{E1} .
- 20 29. The process of any one of embodiments 1 to 28, further comprising passing at least a part of the stream S_{L2} removed from the unit U_{S1} according to (iii.3) as stream S_{L22} into a separation unit U_{S2} , obtaining from the unit a vapor stream S_{VL22} and a liquid stream S_{LL22} , wherein the vapor stream S_{VL22} exhibits a total concentration $c_{VL22}(X)$ of one or more compounds X and a concentration $c_{VL22}(C)$ of monomeric ϵ -caprolactam and wherein the
- 25 liquid stream S_{LL22} exhibits a total concentration $c_{LL22}(X)$ of one or more compounds X and a concentration $c_{LL22}(C)$ of monomeric ϵ -caprolactam, with $c_{LL22}(X) > c_{VL22}(X)$ and $c_{LL22}(C) < c_{VL22}(C)$.
- 30 30. The process of embodiment 29, further comprising passing the aqueous stream S_{VL22} obtained from the separation unit U_{S2} to the water separation unit U_{WS2} , optionally after admixing with the stream S_{V2} .
- 35 31. The process of embodiment 29 or 30, wherein the separation unit U_{S2} comprises, preferably is a drum.
- 40 32. The process of any one of embodiments 1 to 31, further comprising passing at least a part of the stream S_{L1} removed from the unit U_{E1} according to (ii.3) as stream S_{L12} into a separation unit U_{S3} , obtaining from the unit a vapor stream S_{VL12} and a liquid stream S_{LL12} , wherein the vapor stream S_{VL12} exhibits a total concentration $c_{VL12}(X)$ of one or more compounds X and a concentration $c_{VL12}(C)$ of monomeric ϵ -caprolactam and wherein the liquid stream S_{LL12} exhibits a total concentration $c_{LL12}(X)$ of one or more compounds X and a concentration $c_{LL12}(C)$ of monomeric ϵ -caprolactam, with $c_{LL12}(X) > c_{VL12}(X)$ and $c_{LL12}(C) < c_{VL12}(C)$.

33. The process of embodiment 32, wherein at least one of the one or more compounds X comprised in the stream S_{LL12} is an organic polymeric compound, the process further comprising passing at least a part of the stream S_{LL12} to a depolymerization unit.
- 5 34. The process of embodiment 32 or 33, further comprising passing at least a part of the stream S_{VL12} as educt stream in addition to the stream S_{V1} into the cooling unit U_C as defined in embodiment 20.
- 10 35. The process of any one of embodiments 32 to 34, wherein the separation unit comprises, preferably is a thin film evaporator.
36. The process of any one of embodiments 1 to 35, wherein at least one of the one or more compounds X comprised in the stream S_{L12} is an organic polymeric compound, the process further comprising passing at least a part of the stream S_{L12} to a depolymerization unit.
- 15 37. The process of any one of embodiments 1 to 36, wherein the water separation unit U_{WS2} according to (iv) comprises, preferably is a heat-consuming unit, wherein at least part of the heat consumed in U_{WS2} is provided by at least one of the one or more streams S_V according to (i.4) as defined in embodiment 15, thereby obtaining from the at least one stream S_V at least one at least partially condensed aqueous stream S_{WW} .
- 20 38. The process of embodiment 37, wherein the water separation unit U_{WS2} comprises, more preferably is a distillation column equipped with heating means to provide heat for distillation.
- 25 39. The process of any one of embodiments 1 to 38, further comprising obtaining from the water separation unit U_{WS2} an aqueous vapor stream S_{V3} and a liquid stream S_{L3} , the stream S_{V3} exhibiting a concentration $c_{V3}(W)$ of water and a concentration $c_{V3}(C)$ of monomeric ϵ -caprolactam and the stream S_{L3} exhibiting a concentration $c_{L3}(W)$ of water and a concentration $c_{L3}(C)$ of monomeric ϵ -caprolactam, with $c_{L3}(W) < c_{V1}(W)$ and $c_{L3}(C) > c_{V3}(C)$.
- 30 40. The process of embodiment 39, further comprising
- (v) passing the stream S_{L3} into a heat-consuming purification unit U_{P2} , obtaining from S_{L3} a stream S_{CPL} exhibiting a concentration $c_{CPL}(C)$ of monomeric ϵ -caprolactam with $c_{CPL}(C) > c_{L3}(C)$, wherein at least part of the heat consumed in U_{P2} is provided by at least one of the one or more streams S_V according to (i.4) as defined in embodiment 15, thereby obtaining from the at least one stream S_V at least one at least partially condensed aqueous stream S_{WW} .
- 35 40

41. The process of embodiment 40, wherein the heat-consuming purification unit U_{P2} comprises a distillation sub-unit U_{DI} and a crystallization sub-unit U_{CR} , wherein the stream S_{CPL} is preferably obtained from the crystallization sub-unit U_{CR} .
- 5 42. The process of embodiment 41, further comprising providing the stream S_{CPL} to a polyamide 6 production unit U_{PP} , wherein the polyamide 6 produced in U_{PP} is preferably provided as a feedstock to a textile material producing unit U_{TP} , from which unit U_{TP}
- (A) a textile material M_{TE} is obtained which is brought onto the market, wherein, after the life-time T_{TE} of said textile material M_{TE} , it is at least partially collected as textile waste material in a textile material collecting unit U_{TC} ;
- 10 (B) remaining material M_{RTE} is obtained as textile waste material; wherein at least part of the textile waste material according to (A), or at least part of the textile waste material according to (B), or at least part of the textile waste material according to (A) and at least part of the textile waste material according to (B) is suitably provided to U_R as defined in embodiment 15 as S_M .
- 15 43. The process of embodiment 41, further comprising providing the stream S_{CPL} to a polyamide 6 production unit U_{PP} , wherein the polyamide 6 produced in U_{PP} is preferably provided as a feedstock to an engineering plastics material producing unit U_{TP} , from which unit U_{TP}
- 20 (A) an engineering plastics material M_{EP} is obtained which is brought onto the market, wherein, after the life-time T_{EP} of said engineering plastics material M_{EP} , it is at least partially collected as engineering plastics waste material in an engineering plastics material collecting unit U_{TC} ;
- 25 (B) remaining material M_{REF} is obtained as engineering plastics waste material; wherein at least part of the engineering plastics waste material according to (A), or at least part of the engineering plastics waste material according to (B), or at least part of the engineering plastics waste material according to (A) and at least part of the engineering plastics waste material according to (B) is suitably provided to U_R as defined in embodiment 15 as S_M .
- 30 44. Crystallized ϵ -caprolactam, obtainable or obtained as stream S_{CPL} by a process according to any one of embodiments 40 or 41, exhibiting one or more of the following properties:
- 35 - an APHA color, determined as described Reference Example 1, of at most 5, preferably of at most 4, more preferably of at most 3, more preferably of at most 2, more preferably of at most 1.5, more preferably of at most 1;
- a purity, determined as described in Reference Example 2, of at least 99.8 weight-%, preferably of at least 99.9 %, more preferably of at least 99.95 %.
- 40 45. The crystallized ϵ -caprolactam of embodiment 44, exhibiting one or more of the following properties:

- an ϵ -caprolactam oligomer content in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm;
 - a 6-aminocaproic acid content in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm.
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46. The crystallized ϵ -caprolactam of embodiment 44 or 45, exhibiting the following property:
- a triisopropyl borate content in the range of from 0 to 100 weight-ppm, more preferably in the range of from 0 to 50 weight-ppm, more preferably in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm.
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47. The crystallized ϵ -caprolactam of any one of embodiments 44 to 46, preferably wherein the solid material M as defined embodiment 15 comprises one or more elastanes, said crystallized ϵ -caprolactam exhibiting one or more of the following properties:
- a polytetrahydrofuran content in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm;
 - an aniline content in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm;
 - a methylenediphenyl diamine (MDA), isomers and oligomers content in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm;
 - a butanediol content in the range of from 0 to 500 weight-ppm, more preferably in the range of from 0 to 300 weight-ppm, more preferably in the range of from 0 to 100 weight-ppm, more preferably in the range of from 0 to 50 weight-ppm, more preferably in the range of from 0 to 10 weight-ppm; and/or
 - an ethylene glycol content in the range of from 0 to 500 weight-ppm, more preferably in the range of from 0 to 300 weight-ppm, more preferably in the range of from 0 to 100 weight-ppm, more preferably in the range of from 0 to 50 weight-ppm, more preferably in the range of from 0 to 10 weight-ppm.
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48. Use of S_{CPL} , obtainable or obtained by a process according to embodiment 40 or 41, preferably of S_{CPL} according to any one of embodiments 44 to 47, for preparing polyamide 6, said use preferably further comprising employing said polyamide 6 as a feedstock for preparing one or more of at least one textile material and at least one engineering plastics material, more preferably for preparing at least one textile material.
49. Use of a process according to any one of embodiments 1 to 41, preferably of embodiment 40 or 41, for preparing high-purity ϵ -caprolactam from a solid material M, preferably a

waste material comprising polyamide 6 and preferably one or more elastanes, said high-purity ϵ -caprolactam exhibiting one or more of the following properties:

- an ϵ -caprolactam oligomer content in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm;
 - a 6-aminocaproic acid content in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm;
 - a triisopropyl borate content in the range of from 0 to 100 weight-ppm, more preferably in the range of from 0 to 50 weight-ppm, more preferably in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm;
 - a polytetrahydrofuran content in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm;
 - an aniline content in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm;
 - a methylenediphenyl diamine (MDA), isomers and oligomers content in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm;
 - a butanediol content in the range of from 0 to 500 weight-ppm, more preferably in the range of from 0 to 300 weight-ppm, more preferably in the range of from 0 to 100 weight-ppm, more preferably in the range of from 0 to 50 weight-ppm, more preferably in the range of from 0 to 10 weight-ppm; and/or
 - an ethylene glycol content in the range of from 0 to 500 weight-ppm, more preferably in the range of from 0 to 300 weight-ppm, more preferably in the range of from 0 to 100 weight-ppm, more preferably in the range of from 0 to 50 weight-ppm, more preferably in the range of from 0 to 10 weight-ppm.
50. Use of S_{CPL} , obtainable or obtained by a process according to embodiment 40 or 41, preferably of S_{CPL} according to any one of embodiments 44 to 47, 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 40 or 41, preferably of S_{CPL} according to any one of embodiments 44 to 47, as a starting material.
51. The use or the method of embodiment 50, 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.

52. The use or the method of embodiment 50 or 51, 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 40 or 41, preferably being S_{CPL} according to any one of embodiments 44 to 47, wherein the at least one further polymeric compound preferably comprises one or more of at least one polyamide 6.6, at least one polyethylene terephthalate, at least one polyurethane, at least one polyester, at least one cellulose material, and at least one rubber material comprising one or more of at least one natural rubber material and at least one synthetic rubber material.
53. The use or the method of any one of embodiments 50 to 52, 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;
 - 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.

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54. The use or the method of any one of embodiments 50 to 53, 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 40 or 41, preferably being the S_{CPL} according to any one of
- 10 embodiments 44 to 47, 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 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
- 15 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.

55. A process, preferably according to any one of embodiments 1 to 41, comprising the step
- 20 of converting a chemical material obtainable or obtained by the process according to any one of embodiments 1 to 41 to obtain a product Ω .

56. The process of embodiment 55, wherein the product Ω is selected from:
- building block or monomer; or

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 - polymer, preferably polymer A, polymer composition, preferably polymer composition A, or polymer product, preferably polymer product A; or
 - industrial use polymer, industrial use surfactant, descaling compound, industrial use biocide, industrial use solvent, industrial use dispersant, composition thereof or formulation thereof; or

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 - agrochemical composition, agrochemical formulation auxiliary or agrochemically active ingredient; or
 - active pharmaceutical ingredient or intermediate thereof, pharmaceutical excipient, animal feed additive, human food additive, dietary supplements, aroma chemical or aroma composition; or

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 - aqueous polymer dispersion, preferably polyurethane or polyurethane – poly(meth)acrylate hybrid polymer dispersion, emulsion, binder for paper and fiber coatings, UV-curable acrylic polymer for hot melts and coatings polyisocyanates, hyperbranched polyester polyol, polymeric dispersant for inorganic binder compositions, unsaturated polyester polyol or 100% curable composition; or

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 - cosmetic surfactant, emollient, wax, cosmetic polymer, UV filter, further cosmetic ingredient or composition or formulation thereof; or
 - polymer B, polymer composition B, coating composition, other functional composition, foil, molded body, coating or coated substrate.

56. The process of embodiment 55 or 56,
 wherein the content of the chemical material obtainable or obtained by the process
 according to any one of embodiments 1 to 47 in the product Ω is 1 weight-% or more,
 preferably 2 weight-% or more, more preferably 5 weight-% or more, more preferably 15
 weight-% or more, more 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
 wherein the content of the chemical material obtainable or obtained by the process
 according to any one of embodiments 1 to 41 in the product Ω is 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; and preferably wherein the content is determined based on identity preservation
 and/or segregation and/or mass balance and/or book and claim chain of custody models,
 preferably based on mass balance, preferably the International Sustainability and Carbon
 Certification (ISCC) standard.

- As far as the embodiment 54 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. As far as the
 embodiments 50 to 54 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
 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.

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

- The term „elastane“ as used herein is also referred to as „spandex“, and common brand names
 for spandex include Lycra, Elasthan, Acepora, Creora, Inviya, Roica, Dorlastan, Linel or ESPA.

- The term „textile material“ 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 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 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
5 holder and, thus, is an end-of-life material for said holder.

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
10 and physical environments used for example to fabricate plastic parts replacing traditional engineering 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
15 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.

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
20 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 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
25 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 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.

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The present invention are further illustrated in the Reference Examples and Figures.

Description of the figures

35 **Fig. 1** illustrates a process according to the present invention. An aqueous stream S_{L0} which comprises monomeric ϵ -caprolactam and one or more compounds X which have a higher boiling point than monomeric ϵ -caprolactam is passed into an evaporation unit U_{E1} from which an aqueous at least partially vaporous stream S_{V1} and a liquid stream S_{L1} are obtained. The stream S_{V1} is passed to a separation unit U_{S1} from which an aqueous vapor stream S_{V2} and a
40 liquid stream S_{L2} are obtained. The stream S_{V2} is then passed to a water separation unit U_{WS2} .

Fig. 2 illustrates a process according to the present invention. In Fig. 2, the alternative (a) is shown according to which the stream S_{L0} which is passed into the unit U_{E1} is heated from the

temperature T_{L0} to the evaporation temperature T_{E1} via internal heating means H_{INT} arranged within the unit U_{E1} .

Fig. 3 illustrates a process according to the present invention. In Fig. 3, the alternative (b) is shown according to which, in addition to the stream S_{L0} , a stream S_{L11} is passed into the unit U_{E1} , wherein the stream S_{L11} has a temperature T_{L11} with $T_{E1} > T_{L11} > T_{L0}$. By admixing the stream S_{L11} and the stream S_{L0} , and further via the internal heating means H_{INT} , the mixture in U_{E1} is brought to the temperature T_{E1} . According to this process as shown, the stream S_{L1} removed from the unit U_{E1} is divided into two part streams S_{L11} and S_{L12} , wherein the stream S_{L11} has the temperature T_{L11} with $T_{L11} = T_{L1}$.

Fig. 4 illustrates a process according to the present invention. In Fig. 4, the alternative (c) is shown according to which, in addition to the stream S_{L0} , a stream S_{L11H} is passed into the unit U_{E1} , wherein the stream S_{L11H} has a temperature T_{L11H} with $T_{L11H} > T_{E1}$. By admixing the stream S_{L0} and the stream S_{L11H} , the mixture in the unit U_{E1} is brought to the temperature T_{E1} . According to this process, the stream S_{L1} removed from the unit U_{E1} is divided into two part streams S_{L11} and a stream S_{L12} , wherein the stream S_{L11} has a temperature T_{L11} with $T_{L11} = T_{L1}$. The stream S_{L11} is then subjected to heating via external heating means H_{EXT} which are arranged outside the unit U_{E1} , and from said heating, the stream S_{L11H} having the temperature T_{L11H} is obtained.

Fig. 5 illustrates a process according to the present invention. In Fig. 5, a preferred process for providing the stream S_{L0} is shown. According to this preferred process, a stream S_M is provided which comprises a solid material M which in turn comprises polyamide 6. Based on this stream S_M , an aqueous depolymerization mixture is prepared (not shown) and subjected to polyamide 6 depolymerization conditions in a reaction unit U_R . From this unit, a liquid aqueous stream S_R is obtained which comprising ϵ -caprolactam dissolved in water at a concentration c_{SR} and which further comprising one or more impurities. This stream S_R is then to an evaporation unit U_E from which a liquid aqueous stream S_L is obtained which comprises ϵ -caprolactam dissolved in water at a concentration c_{SL} with $c_{SL} > c_{SR}$. Further from the evaporation unit, one or more aqueous vapor streams S_V are obtained (only one stream S_V is shown). The aqueous stream S_L is then passed into a heat-consuming purification unit U_{P1} from which the stream S_{L0} is obtained. Further from the purification unit, one or more aqueous streams S_{RW} (only one stream S_{RW} is shown). At least part of the heat consumed in U_{P1} is provided by at least one of the one or more streams S_V , wherein from the at least one stream S_V , at least one at least partially condensed aqueous stream S_{VW} . It is preferred that at least one these streams S_{VW} (one stream S_{VW} is shown) is at least partially recycled to the reaction unit U_R and at least one stream S_{RW} (one stream S_{RW} is shown) at least partially to the reaction unit U_R .

Fig. 6 illustrates a process according to the present invention. In Fig. 6, a preferred combination of process steps is shown. According to this preferred combination, the purification unit U_{P1} which is shown in Fig. 5 comprises a heat-consuming water separation unit U_{WS1} , and stream S_L (also shown in Fig. 5) is passed to this water separation unit U_{WS1} , thereby obtaining the stream S_{L0} which is then passed to the evaporation unit U_{E1} . Further from the water

separation unit U_{WS1} , an aqueous stream S_A is which preferably an at least partially liquid stream, more preferably a liquid stream. This stream S_A is then used (as the stream S_{CW}) for preparing a stream S_{V1C} from the stream S_{V1} . In particular, the stream S_{V1} removed from the evaporation unit U_{E1} is cooled in a cooling unit U_C by admixing it with the stream S_{CW} (S_A). The
 5 respectively cooled stream S_{V1C} which is preferably a partially condensed stream S_{V1C} is then passed to the separation unit U_{S1} .

Fig. 7 illustrates a process according to the present invention. In Fig. 7, a preferred treatment of the stream S_{L2} is shown which is obtained from the separation unit U_{S1} . In particular,
 10 according to Fig. 7, the stream S_{L2} is divided into two part stream S_{L21} and S_{L22} wherein the first stream S_{L21} is passed as further educt stream, in addition to the stream S_{L0} , into the unit U_{E1} . The other part stream pf S_{L2} , the stream S_{L22} , is passed to a separation unit U_{S2} from which vapor stream S_{VL22} and a liquid stream S_{LL22} are obtained. The vapor stream S_{VL22} exhibits a total concentration $c_{VL22}(X)$ of one or more compounds X and a concentration $c_{VL22}(C)$ of
 15 monomeric ϵ -caprolactam and the liquid stream S_{LL22} exhibits a total concentration $c_{LL22}(X)$ of one or more compounds X and a concentration $c_{LL22}(C)$ of monomeric ϵ -caprolactam, wherein $c_{LL22}(X) > c_{VL22}(X)$ and wherein $c_{LL22}(C) < c_{VL22}(C)$. Further, the Fig. 6 shows a preferred use of said vapor stream S_{VL22} , namely the use as an additional feed stream to the water separation unit U_{WS2} . In Fig. 6, it is shown that the stream S_{VL22} , prior to being fed into U_{WS2} , is suitably
 20 combined with the stream S_{V2} ; it is also conceivable that S_{V2} and S_{VL22} are fed as separate streams into U_{WS2} .

Fig. 8 illustrates a process according to the present invention. In Fig. 8, a preferred use of the stream S_{L12} , already shown in Figures 3 and 4, namely as a feed stream to yet another
 25 separation unit U_{S3} from which, among others, a vapor stream S_{VL12} is obtained. For this stream S_{VL12} , Fig. 8 shows a preferred use. In detail: The part stream S_{L12} which is obtained from the evaporation unit U_{E1} is passed as feed stream to a separation unit U_{S3} . From said unit, a vapor stream S_{VL12} and a liquid stream S_{LL12} are obtained wherein the vapor stream S_{VL12} exhibits a total concentration $c_{VL12}(X)$ of one or more compounds X and a concentration $c_{VL12}(C)$
 30 of monomeric ϵ -caprolactam and wherein the liquid stream S_{LL12} exhibits a total concentration $c_{LL12}(X)$ of one or more compounds X and a concentration $c_{LL12}(C)$ of monomeric ϵ -caprolactam, with $c_{LL12}(X) > c_{VL12}(X)$ and $c_{LL12}(C) < c_{VL12}(C)$. According to a conceivably preferred process design, the vapor stream is passed as further feed stream, in addition to the stream S_{V1} , to the cooling unit U_C where it is admixed with the stream S_{CW} (S_A). Regarding the stream S_{LL12} , it may
 35 be preferred to pass same to a depolymerization unit (not shown).

Fig. 9 illustrates a process according to the present invention. In Fig. 9, it is shown that according to a preferred process design, an aqueous vapor stream S_{V3} and a liquid stream S_{L3} , are obtained from the water separation unit U_{WS2} , wherein the stream S_{V3} exhibits a
 40 concentration $c_{V3}(W)$ of water and a concentration $c_{V3}(C)$ of monomeric ϵ -caprolactam and the stream S_{L3} exhibiting a concentration $c_{L3}(W)$ of water and a concentration $c_{L3}(C)$ of monomeric ϵ -caprolactam, wherein $c_{L3}(W) < c_{V3}(W)$ and $c_{L3}(C) > c_{V3}(C)$. Yet further according to this preferred process design, the stream S_{L3} is passed into a heat-consuming purification unit U_{P2} ,

wherein a preferably highly purified stream S_{CPL} is obtained which a concentration $c_{CPL}(C)$ of monomeric ϵ -caprolactam with $c_{CPL}(C) > c_{L3}(C)$.

Fig. 10 illustrates preferred process steps, most of the mentioned in the context of Figures 1 to 9, in one single overview figure.

Reference Examples

10 Reference Example 1: Determination of the APHA color of crystallized ϵ -caprolactam

The APHA color was determined by according to ISO 8112. In principal, the extinction E of a 50 % by weight aqueous ϵ -caprolactam solution is determined in a cuvette of length $l = 5$ cm at a wavelength $\lambda = 390$ nm and expressed in Hazen units (platinum-cobalt scale). For doing this, the measured extinction E is multiplied by the factor $f = 150$.

The Hazen units (platinum-cobalt scale) are defined as the color of a solution containing, in 1 l water, 1 mg platinum in the form of hexachloroplatinum(IV) acid in the presence of 2 mg cobalt(II) chloride hexahydrate. The Hazen units correspond to the APHA units. A standard solution of 500 Hazen units as prepared as follows: 1.000 g cobalt(II) chloride hexahydrate ($CoCl_2 \cdot 6 H_2O$) and 1.245 g potassium hexachloroplatinate(IV) (K_2PtCl_6) are dissolved in 100 ml hydrochloric acid having a of 1.19 g/ml. The solution is transferred into a 1000 ml volumetric flask which is filled to the calibration mark. Thus solution contains 500 mg platinum and corresponds to 500 Hazen units. 50 ± 0.1 g ϵ -caprolactam are dissolved in a 250 Erlenmeyer flask in 50 ml distilled water. The solution is mixed and left until the air bubbles have disappeared. The 2 cuvettes of the spectrophotometer (which is suitable for measurements at a wavelength $\lambda = 390$ nm) are filled with distilled water, placed in the beam path, and the spectrophotometer is adjusted at $\lambda = 390$ nm to $E = 0$. Then, the distilled water is removed from the sample cuvette, followed by filling this cuvette with the ϵ -caprolactam solution. Then, the extinction E of this solution is determined at $\lambda = 390$ nm (E_{390}) against the comparative cuvette containing distilled water. The color number X (Hazen units, platinum-cobalt scale) is calculated as $X = E \cdot f = 150 \cdot E_{390}$. X is rounded to the next integer.

35 Reference Example 2: Determination of the purity of crystallized ϵ -caprolactam

For GC analysis on purity of the crystallized ϵ -caprolactam, samples were prepared in deionized water at concentration of approx. 200 mg/mL. 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 (~ 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.

5 According to the present invention, it was found that, if impurities are present in S_{CPL} , and in particular in case one or more elastanes are contained in the solid material M, diol compounds such as butanediol and ethylene glycol, and optionally oligomers thereof, are the predominant impurities.

10

Claims

1. A process for separating one or more organic compounds X from an aqueous liquid stream S_{L0} comprising monomeric ϵ -caprolactam and said one or more compounds X, the process comprising
 - (i) providing the stream S_{L0} having a temperature T_{L0} and exhibiting a total concentration $c_{L0}(X)$ of the one or more compounds X and a concentration $c_{L0}(C)$ of monomeric ϵ -caprolactam;
 - (ii) producing in an evaporation unit U_{E1} from the stream S_{L0} an aqueous at least partially vaporous stream S_{V1} and a liquid stream S_{L1} , comprising
 - (ii.1) passing the stream S_{L0} provided according to (i) into the unit U_{E1} , preparing in the unit U_{E1} from the stream S_{L0} an evaporation mixture M_{E1} having an evaporation temperature T_{E1} at an evaporation pressure p_{E1} with $T_{E1} > T_{L0}$, wherein the one or more organic compounds X have a boiling point T_{BX} and ϵ -caprolactam has a boiling point T_{BC} with $T_{BX} > T_{E1} \geq T_{BC}$ at the evaporation pressure p_{E1} ;
 - (ii.2) removing the stream S_{V1} from the evaporation unit U_{E1} , the stream S_{V1} having a temperature T_{V1} with $T_{V1} \leq T_{E1}$ and exhibiting a total concentration $c_{V1}(X)$ of one or more compounds X and a concentration $c_{V1}(C)$ of monomeric ϵ -caprolactam with $c_{V1}(C) > c_{L0}(C)$ and $c_{V1}(X) < c_{L0}(X)$;
 - (ii.3) removing the stream S_{L1} from the evaporation unit U_{E1} , the stream S_{L1} having a temperature T_{L1} with $T_{L1} = T_{E1}$ and exhibiting a total concentration $c_{L1}(X)$ of one or more compounds X and a concentration $c_{L1}(C)$ of monomeric ϵ -caprolactam with $c_{L1}(C) < c_{E1}(C)$ and $c_{L1}(X) > c_{L0}(X)$;
 - (iii) producing in a separation unit U_{S1} from the stream S_{V1} an aqueous vapor stream S_{V2} and a liquid stream S_{L2} , comprising
 - (iii.1) passing the stream S_{V1} removed from the evaporation unit U_{E1} according to (ii.2), optionally after cooling, into the separation unit U_{S1} and subjecting the stream S_{V1} , optionally the stream after cooling, in the separation unit U_{S1} to separation conditions;
 - (iii.2) removing the stream S_{V2} from the separation unit U_{S1} , the stream S_{V2} having a temperature T_{V2} with $T_{L0} < T_{V2} \leq T_{V1}$ and exhibiting a total concentration $c_{V2}(X)$ of one or more compounds X and a concentration $c_{V2}(C)$ of monomeric ϵ -caprolactam;
 - (iii.3) removing the stream S_{L2} from the separation unit U_{S1} , the stream S_{L2} having a temperature T_{L2} with $T_{L2} = T_{V2}$ and exhibiting a total concentration $c_{L2}(X)$ of one or more compounds X and a concentration $c_{L2}(C)$ of monomeric ϵ -caprolactam with $c_{L2}(X) > c_{V2}(X)$ and $c_{L2}(C) < c_{V2}(C)$;
 - (iv) passing the aqueous stream S_{V2} obtained from the separation unit U_{S1} according to (iii.2) to a water separation unit U_{WS2} .
2. The process of claim 1, wherein T_{L0} is in the range of from 75 to 120 °C, preferably in the range of from 80 to 110 °C, more preferably in the range of from 85 to 100 °C.

3. The process of claim 1 or 2, wherein $c_{L0}(C) + c_{L0}(X)$ is at least 60 weight-%, preferably in the range of from 60 to weight-%, more preferably in the range of from 70 to 90 weight-%, more preferably in the range of from 80 to 85 weight-%, wherein in the stream S_{L0} , the weight ratio of the one or more compounds X to monomeric ϵ -caprolactam is preferably in the range of from 50:50 to 5:95.
4. The process of any one of claims 1 to 3, wherein the one or more compounds X comprised in the stream S_{L0} comprise at least one of
- at least one aromatic amine which includes at least one of an aromatic monoamine, an aromatic diamine, an aromatic triamine and an aromatic tetramine;
 - at least one aliphatic amine which includes at least one of an aliphatic monoamine, an aliphatic diamine and an aliphatic triamine;
 - at least one aliphatic amide;
 - at least one aromatic alcohol which includes at least one of an aromatic monool and an aromatic diol;
 - at least one aliphatic alcohol which includes at least one of an aliphatic monool and an aliphatic diol;
 - at least one aromatic acid;
 - at least one and aliphatic acid;
 - at least one ϵ -caprolactam oligomer;
 - at least other compound selected from the group consisting of one or more cleavage products of dyes such as optionally chlorinated aromatic diamines, one or more water-soluble oligomeric cellulose cleavage products, and one or more water-soluble oligomers of terephthalic acid and hexamethylenediamine.
5. The process of any one of claims 1 to 4, wherein the stream S_{L0} exhibits a concentration $c_{L0}(W)$ of water and wherein $c_{L0}(W)$ is in the range of from 5 to 40 weight-%, preferably in the range of from 10 to 30 weight-%, more preferably in the range of from 15 to 20 weight-%, wherein preferably from 98 to 100 weight-%, more preferably from 99 to 100 weight-%, more preferably from 99.5 to 100 weight-%, more preferably from 99.9 to 100 weight-% of S_{L0} consist of the one or more compounds X, monomeric ϵ -caprolactam, and water.
6. The process of any one of claims 1 to 5, wherein p_{E1} is in the range of from 50 to 200 mbar and T_{E1} is in the range of from 220 to 330 °C, preferably in the range of from 240 to 320 °C, more preferably in the range of from 260 to 300 °C; wherein preparing the mixture M_{E1} in the unit U_{E1} according to (ii.1) preferably comprises
- (a) heating the stream S_{L0} passed into the unit U_{E1} from the temperature T_{L0} to the evaporation temperature T_{E1} via internal heating means H_{INT} arranged within the unit U_{E1} , thereby obtaining the evaporation mixture M_{E1} ;
 - or preferably comprises
 - (b) passing, in addition to the stream S_{L0} , a stream S_{L11} into the unit U_{E1} , the stream S_{L11} having a temperature T_{L11} with $T_{E1} > T_{L11} > T_{L0}$, admixing the stream S_{L11} and the

- stream S_{L0} and heating the obtained mixture to the temperature T_{E1} via internal heating means H_{INT} arranged within the unit U_{E1} , thereby obtaining the evaporation mixture M_{E1} , wherein the process further comprises
- (ii.4) dividing the stream S_{L1} removed from the unit U_{E1} according to (ii.3) into at least two part streams comprising the stream S_{L11} and a stream S_{L12} , wherein the stream S_{L11} has the temperature T_{L11} with $T_{L11} = T_{L1}$;
- or preferably comprises
- (c) passing, in addition to the stream S_{L0} , a stream S_{L11H} into the unit U_{E1} , the stream S_{L11H} having a temperature T_{L11H} with $T_{L11H} > T_{E1}$, and admixing the stream S_{L0} and the stream S_{L11H} , thereby obtaining the evaporation mixture M_{E1} , wherein the process further comprises
- (ii.4) dividing the stream S_{L1} removed from the unit U_{E1} according to (ii.3) into at least two part streams comprising a stream S_{L11} and a stream S_{L12} , wherein the stream S_{L11} has a temperature T_{L11} with $T_{L11} = T_{L1}$;
- (ii.5) subjecting the stream S_{L11} obtained according to (ii.4) to heating via external heating means H_{EXT} arranged outside the unit U_{E1} , obtaining the stream S_{L11H} having the temperature T_{L11H} .
7. The process of claim 6, wherein according to (c), wherein $T_{L11H} \geq (T_{E1} + 10 \text{ K})$, preferably $T_{L11H} \geq (T_{E1} + 20 \text{ K})$, more preferably $T_{L11H} \geq (T_{E1} + 30 \text{ K})$.
8. The process of any one of claims 1 to 7, wherein providing the stream S_{L0} according to (i) comprises, and/or wherein the stream S_{L0} is obtainable or obtained by a method comprising
- (i.1) providing a stream S_M comprising a solid material M comprising polyamide 6;
- (i.2) preparing an aqueous depolymerization mixture based on S_M ;
- (i.3) subjecting the depolymerization mixture prepared according to (i.2) to polyamide 6 depolymerization conditions in a reaction unit U_R , obtaining a liquid aqueous stream S_R comprising ϵ -caprolactam dissolved in water at a concentration c_{SR} , the stream S_R further comprising one or more impurities;
- (i.4) passing the liquid aqueous stream S_R into an evaporation unit U_E , obtaining from S_R 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_R one or more aqueous vapor streams S_V ;
- (i.5) passing the aqueous stream S_L into a heat-consuming purification unit U_{P1} , obtaining from S_L the stream S_{L0} and further obtaining from S_L one or more aqueous streams S_{RW} , wherein at least part of the heat consumed in U_{P1} 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} ;
- (i.6) preferably recycling at least one stream S_{VW} at least partially to the reaction unit U_R and at least one stream S_{RW} at least partially to the reaction unit U_R ;
- wherein the solid material M preferably comprises, more preferably consists of, waste material, wherein said waste material more preferably comprises, more preferably

- consists of, one or more of at least one textile waste material and at least one engineering plastics waste material, more preferably comprises, more preferably consists of at least one textile waste material;
- wherein preferably from 10 to 99 weight-%, more preferably from 30 to 98.5 weight-%, more preferably from 50 to 98 weight-%, more preferably from 80 to 98 weight-%, of the solid material M consist of the polyamide;
- wherein preferably, in addition to polyamide 6, the solid material M comprises one or more further organic polymeric compounds, more preferably including, but not limited to, one or more of at least one elastanes, at least one polyethylene terephthalate, at least one polytetrahydrofuran, at least one polyamide 6.6, at least one polyurethane, at least one polyester, at least one cellulose material, and at least one rubber material comprising one or more of at least one natural rubber material and at least one synthetic rubber material.
9. The process of claim 8, wherein the purification unit U_{P1} according to (i.5) comprises a heat-consuming water separation unit U_{WS1} , the process comprising feeding the stream S_L to U_{WS1} , obtaining from U_{WS1} the stream S_{L0} , wherein in addition to the S_{L0} , an aqueous stream S_A is preferably obtained from U_{WS1} , wherein the stream S_A is preferably an at least partially liquid stream, more preferably a liquid stream which, more preferably, exhibits a water concentration $c_A(W)$ of at least 95 weight-%, more preferably of at least 98 weight-%, more preferably of at least 99 weight-%, wherein the stream S_A optionally comprises ϵ -caprolactam, and wherein, more preferably, the stream S_A has a temperature T_A , wherein T_A is in the range of from 15 to 95 °C, more preferably in the range of from 20 to 90 °C, more preferably in the range of from 25 to 85 °C, wherein more preferably $T_A \leq T_{L0}$, more preferably $T_A < T_{L0}$.
10. The process of any one of claims 1 to 9, wherein (iii.1) comprises
- (iii.1) subjecting the stream S_{V1} removed from the evaporation unit U_{E1} according to (ii.2), to cooling in cooling unit U_C , obtaining from the unit U_C a cooled stream S_{V1C} , preferably obtaining a cooled and partially condensed stream S_{V1C} , passing the stream S_{V1C} into the separation unit U_{S1} and subjecting the stream S_{V1C} in the separation unit U_{S1} to separation conditions;
- wherein according to (iii.1), subjecting the stream S_{V1} to cooling in the unit U_C preferably comprises admixing the stream S_{V1} in the unit U_C with an aqueous stream S_{CW} , more preferably with an at least partially liquid aqueous stream S_{CW} , more preferably with a liquid aqueous stream S_{CW} , said aqueous stream S_{CW} having a temperature T_{CW} with $T_{CW} < T_{V1}$, preferably with $T_{CW} \leq T_{L0}$;
- wherein the stream S_{V1C} has a temperature T_{V1C} preferably in the range of from 160 to 330 °C, more preferably in the range of from 170 to 320 °C, more preferably in the range of from 170 to 300 °C;
- wherein preferably from 95 to 100 weight-%, more preferably from 98 to 100 weight-%, more preferably from 99 to 100 weight-% of the stream T_{CW} consist of water.

11. The process of any one of claims 1 to 10, wherein the unit U_{E1} comprises a stirred reactor, more preferably a stirred tank reactor, more preferably a continuous stirred tank reactor, and wherein the separation unit U_{S1} comprises, preferably consists of, a droplet separator, preferably selected from the group consisting of a hydrocyclone, a demister plate, and an absorption tower, more preferably a hydrocyclone.
12. The process of any one of claims 1 to 11, further comprising passing at least a part of the stream S_{L2} removed from the unit U_{S1} according to (iii.3) as educt stream S_{L21} in addition to the stream S_{L0} , into the unit U_{E1} .
13. The process of any one of claims 1 to 12, further comprising passing at least a part of the stream S_{L2} removed from the unit U_{S1} according to (iii.3) as stream S_{L22} into a separation unit U_{S2} , obtaining from the unit a vapor stream S_{VL22} and a liquid stream S_{LL22} , wherein the vapor stream S_{VL22} exhibits a total concentration $c_{VL22}(X)$ of one or more compounds X and a concentration $c_{VL22}(C)$ of monomeric ϵ -caprolactam and wherein the liquid stream S_{LL22} exhibits a total concentration $c_{LL22}(X)$ of one or more compounds X and a concentration $c_{LL22}(C)$ of monomeric ϵ -caprolactam, with $c_{LL22}(X) > c_{VL22}(X)$ and $c_{LL22}(C) < c_{VL22}(C)$; the process preferably further comprising passing the aqueous stream S_{VL22} obtained from the separation unit U_{S2} to the water separation unit U_{WS2} , optionally after admixing with the stream S_{V2} .
14. The process of any one of claims 1 to 13, further comprising passing at least a part of the stream S_{L1} removed from the unit U_{E1} according to (ii.3) as stream S_{L12} into a separation unit U_{S3} , obtaining from the unit a vapor stream S_{VL12} and a liquid stream S_{LL12} , wherein the vapor stream S_{VL12} exhibits a total concentration $c_{VL12}(X)$ of one or more compounds X and a concentration $c_{VL12}(C)$ of monomeric ϵ -caprolactam and wherein the liquid stream S_{LL12} exhibits a total concentration $c_{LL12}(X)$ of one or more compounds X and a concentration $c_{LL12}(C)$ of monomeric ϵ -caprolactam, with $c_{LL12}(X) > c_{VL12}(X)$ and $c_{LL12}(C) < c_{VL12}(C)$; wherein preferably at least one of the one or more compounds X comprised in the stream S_{LL12} is an organic polymeric compound, the process preferably further comprising passing at least a part of the stream S_{LL12} to a depolymerization unit; wherein the process more preferably further comprises passing at least a part of the stream S_{VL12} as educt stream in addition to the stream S_{V1} into the cooling unit U_C .
15. The process of any one of claims 1 to 14, wherein the water separation unit U_{WS2} according to (iv) comprises, preferably is a heat-consuming unit, wherein at least part of the heat consumed in U_{WS2} is provided by at least one of the one or more streams S_V according to (i.4) as defined in claim 8, thereby obtaining from the at least one stream S_V at least one at least partially condensed aqueous stream S_{VW} ; the process preferably further comprising obtaining from the water separation unit U_{WS2} an aqueous vapor stream S_{V3} and a liquid stream S_{L3} , the stream S_{V3} exhibiting a concentration $c_{V3}(W)$ of water and a concentration $c_{V3}(C)$ of monomeric ϵ -caprolactam and

the stream S_{L3} exhibiting a concentration $c_{L3}(W)$ of water and a concentration $c_{L3}(C)$ of monomeric ϵ -caprolactam, with $c_{L3}(W) < c_{V1}(W)$ and $c_{L3}(C) > c_{V3}(C)$.

16. The process of claim 15, further comprising
 - 5 (v) passing the stream S_{L3} into a heat-consuming purification unit U_{P2} , obtaining from S_{L3} a stream S_{CPL} exhibiting a concentration $c_{CPL}(C)$ of monomeric ϵ -caprolactam with $c_{CPL}(C) > c_{L3}(C)$, wherein at least part of the heat consumed in U_{P2} is provided by at least one of the one or more streams S_V according to (i.4) as defined in embodiment 15, thereby obtaining from the at least one stream S_V at least one at
 - 10 least partially condensed aqueous stream S_{VW} ;
 wherein the heat-consuming purification unit U_{P2} preferably comprises a distillation sub-unit U_{DI} and a crystallization sub-unit U_{CR} , wherein the stream S_{CPL} is preferably obtained from the crystallization sub-unit U_{CR} .
- 15 17. Crystallized ϵ -caprolactam, obtainable or obtained as stream S_{CPL} by a process according to claim 16, preferably exhibiting one or more of the following properties:
 - an APHA color, determined as described Reference Example 1, of at most 5, preferably of at most 4, more preferably of at most 3, more preferably of at most 2, more preferably of at most 1.5, more preferably of at most 1;
 - 20 - a purity, determined as described in Reference Example 2, of at least 99.8 weight-%, preferably of at least 99.9 %, more preferably of at least 99.95 %;
 more preferably further exhibiting one or more of the following properties:
 - an ϵ -caprolactam oligomer content in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of
 - 25 from 0 to 1 weight-ppm;
 - a 6-aminocaproic acid content in the range of from 0 to 10 weight-ppm, more preferably in the range of from 0 to 5 weight-ppm, more preferably in the range of from 0 to 1 weight-ppm.
- 30 18. Use of S_{CPL} , obtainable or obtained by a process according to claim 16, preferably of S_{CPL} according to claim 17, for preparing polyamide 6, said use preferably further comprising employing said polyamide 6 as a feedstock for preparing one or more of at least one textile material and at least one engineering plastics material, more preferably for preparing at least one textile material.
- 35 19. A process, preferably according to any one of claims 1 to 16, comprising the step of converting a chemical material obtainable or obtained by the process according to any one of claims 1 to 16 to obtain a product Ω .