

Highly integrated caprolactam recycling process

The present invention relates to a highly integrated recycling process, specifically for recycling ϵ -caprolactam from a solid material which comprises a polymer prepared from ϵ -caprolactam, specifically polyamide 6.

Polyamide, and in particular polyamide 6 being characterized by the formula $(-\text{NH}-(\text{CH}_2)_5-\text{CO}-)_n$, can be found in numerous materials, such as packaging, engineering plastics from automotive and textile filaments. The latter represents about 40 % of the polyamide 6 global market. At present, only a very small part of the textile filaments is recycled while it represents a significant percentage of the global CO_2 emissions. Thus, there is a need to recycle polyamide 6 from such materials. Processes for alkaline depolymerizing a polyamide exists. However, such processes have a certain CO_2 footprint and are energy-intensive. Therefore, there is a need to provide an improved process for depolymerizing a polyamide able to overcome these issues.

Accordingly, a highly integrated recycle process is needed to achieve the above-mentioned goal. Thus, according to the present invention, a process is provided wherein waste material comprising polyamide 6 is subjected to hydrolytic depolymerization and the respectively obtained liquid aqueous stream is advantageously treated to combine heat integration aspects as well as water recovery aspects in order to render the overall process as efficient and economically advantageous as possible.

Therefore, the present invention relates to a recycling process for recovering ϵ -caprolactam from a solid material M comprising polyamide 6, the process comprising

- (i) providing a stream S_M comprising the solid material M;
- (ii) preparing an aqueous depolymerization mixture based on S_M ;
- (iii) subjecting the depolymerization mixture prepared according to (ii) 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;
- (iv) 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 ;
- (v) passing the aqueous stream S_L into a heat-consuming purification unit U_P , obtaining from S_L a stream S_{CPL} comprising ϵ -caprolactam at a concentration c_{SCPL} with $c_{SCPL} \gg c_{SL}$, and further obtaining from S_L one or more aqueous streams S_{RW} , wherein at least part of the heat consumed in U_P is provided by at least one of the one or more streams S_V , thereby obtaining from the at least one stream S_V at least one at least partially condensed aqueous stream S_{WW} ;
- (vi) 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 .

According to (i), a stream S_M is provided which comprises the solid material. Preferably, the solid material M 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. 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 M consist of the polyamide; or preferably from 10 to 100 weight-%, more preferably from 30 to 100 weight-%, more preferably from 50 to 100 weight-%, more preferably from 80 to 100 weight-%, of M consist of the polyamide. If the polyamide 6 content of the solid material M is less than 100 weight-%, it may be preferred that the solid material M additionally comprises one or more elastanes. Generally, the solid material M may comprise, in addition to polyamide 6, at least one further polymeric compound, 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 polyether; at least one polyvinyl chloride; at least natural fiber material such as wool and cotton; at least one cellulose material; at least one natural elastomer; at least one synthetic elastomer; at least one copolymer of two or more of said polymeric compounds including statistical copolymers, gradient copolymers, alternating copolymers, block copolymers, and graft copolymers; and at least one rubber material comprising one or more of at least one natural rubber material and at least one synthetic rubber material.

Preferably, the solid material M is in the form of granules, wherein the mean diameter of the granules is preferably in the range of from 0.5 to 10 mm, more preferably in the range of from 1 to 7 mm, more preferably in the range of from 2 to 4 mm.

According to (ii), an aqueous depolymerization mixture is prepared based on S_M . While there are no specific restrictions how this depolymerization mixture is prepared, it may be preferred to providing the stream S_M , to provide a liquid aqueous stream S_W , wherein preferably from 90 to 100 weight-% of S_W consist of water, to feed the stream S_M and the liquid aqueous stream S_W into the chemical reaction unit U_R according to (iii), to obtaining the aqueous depolymerization mixture in U_R . Preferably, the depolymerization mixture which is subjected to polyamide 6 depolymerization conditions according to (iii) exhibits a mixing ratio $m_W/kg : m_P/kg$, defined as the amount of water contained in S_W , m_W , relative to the mass of polyamide 6 contained in the solid material M, m_P , 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.

According to (iii), the depolymerization mixture is subjected to polyamide 6 depolymerization conditions in the reaction unit U_R . Said depolymerization conditions comprise a polyamide 6 depolymerization temperature T_D and a polyamide 6 depolymerization pressure p_D , wherein T_D is in the range of from 230 to 330 °C and p_D is in the range of from 40 to 140 bar, preferably wherein T_D is in the range of from 250 to 320 °C and p_D is in the range of from 40 to 125 bar,

more preferably wherein T_D is in the range of from 270 to 310 °C and p_D is in the range of from 40 to 110 bar.

- 5 Preferably, the chemical 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, more preferably in the range of from 2 to 8, more preferably in the range of from 2 to 6, more preferably in the range of from 2 to 5, more preferably in the range of from 2 to 4, more preferably 3 or 4. Preferably, $z>1$ and at least two reactors R_i , more preferably the z reactors R_i , are serially coupled, wherein, if the z reactors R_i are serially coupled,
- the solid material M and S_W are preferably fed into R_i , $i=1$;
 - 10 - an aqueous liquid stream S_i containing ϵ -caprolactam dissolved in water is removed from R_i and fed into R_{i+1} , $i<z$;
 - S_R is removed from R_z ;

- wherein in every reactor R_i , a polyamide 6 depolymerization temperature T_{Di} at a polyamide 6 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. Preferably, maintaining a depolymerization temperature T_{Di} in a reactor R_i comprises heating the reactor contents of R_i , more preferably indirectly heating the reactor contents of R_i , wherein more
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- 20 preferably, maintaining a depolymerization temperature T_{Di} in a reactor R_i comprises heating the reactor contents of R_i by passing a heating medium through a heating jacket of R_i . The heating medium is preferably hot oil. Other heating media known by the skilled person can be used for passing through the heating jacket of R_i . Preferably, for $z>1$, the z reactors R_i are vertically arranged, with R_1 being the top-most reactor and R_z being the bottom-most reactor, wherein S_i
- 25 obtained from R_i is transferred to R_{i+1} by gravity, more preferably by gravity only.

- Preferably, the overall residence time in the chemical reaction unit U_R is in the range of from 15 to 160 minutes, more preferably in the range of from 20 to 120 minutes, more preferably in the range of from 25 to 100 minutes, more preferably in the range of from 30 to 90 minutes.

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Preferably, the aqueous liquid stream S_R has a temperature T_R in the range of from 230 to 330 °C, more preferably in the range of from 250 to 320 °C, more preferably in the range of from 270 to 310 °C.

- 35 Preferably according to the present invention, 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 added for preparing the depolymerization mixture.

- 40 If the solid material M comprises one or more elastanes, the aqueous liquid stream S_R 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 a melting

unit upstream of the reaction unit U_R , in which melting unit the solid material M is suitably melted, leading to a liquid stream which is then passed into U_R . In this case, preparing an aqueous depolymerization mixture based on S_M according to step (ii) of the process of the present invention may preferably comprise

- 5 (ii.1) melting in a melting unit the solid material M provided according to (i), obtaining a liquid stream, wherein the melting unit preferably comprises a kneader or an extruder, more preferably an extruder, and wherein the melting temperature is preferably in the range of from 230 to 330 °C, more preferably in the range of from 250 to 320 °C, more preferably in the range of from 270 to 310 °C;
- 10 (ii.2) providing a liquid aqueous stream;
- (ii.3) admixing in a pre-reaction unit the stream obtained according to (ii.1) with the stream provided according to (ii.3), obtaining a liquid reaction feed stream, wherein the pre-reaction unit preferably comprises a mixing unit, more preferably a static mixing unit;
- 15 (ii.4) feeding the stream obtained according to (i.3) as depolymerization mixture into the chemical reaction unit U_R .

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
20 such as 2,4'-methylenedianiline and 2,2'-methylenedianiline.

According to (iv), the liquid aqueous stream S_R is passed 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
25 streams S_V .

Preferably, the evaporation unit U_E comprises two or more evaporation sub-units, the process comprising obtaining at least at least two vapor streams S_{V1} and S_{V2} , passing the vapor stream S_{V1} to at least one heat-consuming unit and passing the vapor stream S_{V2} to at least one heat-
30 consuming unit, wherein the vapor streams S_{V1} and S_{V2} differ from each other in either pressure and/or temperature. More preferably, the process comprises subjecting the aqueous liquid stream S_R to depressurization in an evaporation unit U_E comprising n evaporation sub-units $U_E(j)$, $1 \leq j \leq n$ with $n \geq 1$, obtaining from each sub-unit $U_E(j)$ an aqueous vapor stream S_{Vj} and an aqueous liquid stream S_{Lj} comprising ϵ -caprolactam dissolved in water, wherein S_{Vj} has a temperature T_{Vj}
35 and a pressure p_{Vj} and wherein S_{Lj} has a temperature T_{Lj} and a pressure p_{Lj} , wherein at least one evaporation sub-unit $U_E(j)$, more preferably every evaporation sub-unit $U_E(j)$ comprises, more preferably consists of, a flash drum. Preferably, $n > 1$, wherein for $j < n$, the process comprises passing the aqueous liquid stream S_{Lj} obtained from the evaporation sub-unit $U_E(j)$ as feed stream into the evaporation sub-unit $U_E(j+1)$. More preferably, the n evaporation sub-units $U_E(j)$
40 are serially coupled. More preferably, $n > 1$, wherein for $j < n$, $T_{V(j+1)} < T_{Vj}$; $p_{V(j+1)} < p_{Vj}$; $T_{L(j+1)} < T_{Lj}$; and $p_{L(j+1)} < p_{Lj}$.

Optionally, the process comprises passing the aqueous liquid stream S_R through a heat exchanging unit upstream of U_E , obtaining from this heat exchanging unit a cooled stream S_R .

According to (v), the aqueous stream S_L is passed into a heat-consuming purification unit U_P ,
 5 obtaining from S_L a stream S_{CPL} comprising ϵ -caprolactam at a concentration c_{SCPL} with
 $c_{SCPL} \gg c_{SL}$, and further obtaining from S_L one or more aqueous streams S_{RW} , wherein at least
 part of the heat consumed in U_P is provided by at least one of the one or more streams S_V ,
 thereby obtaining from the at least one stream S_V at least one at least partially condensed
 aqueous stream S_{VW} . The abbreviation " $\gg$ " as used in this context illustrates that the
 10 concentration c_{SCPL} is significantly higher than the concentration c_{SL} , wherein, preferably, the
 stream S_{CPL} ultimately obtained from the purification unit U_P comprises, preferably consists of,
 substantially pure ϵ -caprolactam.

Preferably, the purification unit U_P comprises one or more of a heat-consuming water separation
 15 unit U_{WS} , a heat-consuming distillation unit U_D and a heat-consuming crystallization unit U_C ,
 preferably two or more of a heat-consuming water separation unit U_{WS} , a heat-consuming
 distillation unit U_D and a heat-consuming crystallization unit U_C , more preferably a heat-
 consuming water separation unit U_{WS} , a heat-consuming distillation unit U_D and a heat-consuming
 crystallization unit U_C , wherein at least part of the heat consumed in one or more of U_{WS} , U_D and
 20 U_C is provided by at least one of the one or more streams S_V . More preferably, the purification
 unit U_P comprises a heat-consuming water separation unit U_{WS} , a heat-consuming distillation unit
 U_D and a heat-consuming crystallization unit U_C , wherein U_{WS} is located upstream of U_D and U_D is
 located upstream of U_C .

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

Preferably, at least one stream S_V is used for providing at least a part of the heat consumed in
 35 U_{WS} . By providing said heat to U_{WS} , at least one of said streams S_V is at least partially condensed.
 Alternatively or additionally, at least one stream S_V is used for providing at least a part of the heat
 consumed in U_D . By providing said heat to U_D , at least one of said streams S_V is at least partially
 condensed. Alternatively or additionally, at least one stream S_V is used for providing at least a
 part of the heat consumed in U_C . By providing said heat to U_C , at least one of said streams S_V is
 40 at least partially condensed. Therefore, the process preferably comprises one or more of (i-1), (i-
 2) and (i-3); preferably at least two or more of (i-1), (i-2) and (i-3); more preferably (i-1), (i-2) and
 (i-3):

- (i-1) obtaining at least one at least partially condensed aqueous stream S_{VW1} from U_{WS} ;
 (i-2) obtaining at least one at least partially condensed aqueous stream S_{VW2} from U_D ;
 (i-3) obtaining at least one at least partially condensed aqueous stream S_{VW3} from U_C ;
 wherein it is more preferred that one or more S_{VW1} , S_{VW2} and S_{VW3} ; preferably two or more S_{VW1} ,
 5 S_{VW2} and S_{VW3} ; more preferably S_{VW1} , S_{VW2} and S_{VW3} are fed into the water treatment unit U_W .

In the water separation unit U_{WS} , water is separated from the liquid aqueous stream S_L . From S_L having been passed into U_{WS} , a stream S_{UWS} is preferably obtained, being purified with respect to ϵ -caprolactam, wherein S_{UWS} is preferably passed to a further downstream purification sub-unit,
 10 more preferably to the purification sub-unit U_D . Further, from U_{WS} and based on S_L , at least one of the one or more aqueous streams S_{RW} according to (v) is obtained which is then preferably fed to the water treatment unit U_W .

- More preferably, the water separation unit U_{WS} comprises at least two heat-consuming water
 15 separation sub-units U_{WS1} and U_{WS2} , preferably two serially coupled heat-consuming water separation sub-units U_{WS1} and U_{WS2} , wherein the stream S_L is fed into U_{WS1} and wherein at least part of the heat consumed in one or more of U_{WS1} and U_{WS2} is provided by at least one of the one or more streams S_V . More preferably, the process comprises one or more of (ii-1) and (ii-2) preferably (ii-1) and (ii-2):
 20 (ii-1) obtaining at least one at least partially condensed aqueous stream S_{VW11} from U_{WS1} ;
 (ii-2) obtaining at least one at least partially condensed aqueous stream S_{VW12} from U_{WS2} .

While not being restricted to any specific purification units, it is preferred according to the present invention that U_{WS1} is an evaporation unit, preferably comprising a film evaporator, more
 25 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. Preferably, U_{WS2} comprises, more preferably consists of, a distillation column equipped with heating means to provide heat for distillation. Preferably, at least one aqueous stream S_{RW1} is
 30 obtained from U_{WS1} and further preferably, at least one aqueous stream S_{RW2} is obtained from U_{WS2} . More preferably, at least one of S_{RW1} and S_{RW2} , more preferably S_{RW1} and S_{RW2} , are fed into the water treatment unit U_W .

It is further preferred that downstream of U_{WS1} and upstream of U_{WS2} , a separation unit U_I is
 35 arranged which serves for separating impurities from the aqueous stream comprising ϵ -caprolactam obtained from U_{WS1} before it is passed to the second purification sub-unit U_{WS2} . Therefore, the process preferably comprises obtaining from U_{WS1} an aqueous stream S_{UWS1} , feeding the stream S_{UWS1} into the separation unit U_I , obtaining from U_I an aqueous stream S_{UI} , and feeding the stream S_{UI} into the unit U_{WS2} , wherein in U_I , one or more of impurities are
 40 separated from S_{UWS1} , thereby obtaining from U_I an impurity stream S_I , said impurities preferably comprising at least one impurity comprised in S_R according to (ii). According to the present invention, it is preferred that in U_I , an ϵ -caprolactam oligomeric compound is separated from the

stream S_{UWS1} . Regarding the separation of impurities in U_I , the process more preferably comprises

- (a) preparing an aqueous liquid mixture M_E comprising the stream S_{UWS1} obtained from U_{WS1} ;
 - (b) subjecting the mixture M_E according to (a) to evaporation conditions in an evaporation unit E_1 , obtaining an aqueous vapor stream S_{U1} and an aqueous liquid stream S_I ;
 - (c) dividing the stream S_I according to (b) into a first stream S_{I1} and a second stream S_{I2} , wherein S_{I1} and S_{I2} have the same chemical composition as S_I ;
 - (d) optionally passing the stream S_{I2} obtained according to (c) to a suitable downstream treatment stage;
- wherein preparing the aqueous liquid mixture M_E according to (a) comprises mixing the stream S_{UWS1} with the stream S_{I1} . The evaporation in the evaporation unit E_1 according to (b) is preferably carried out in one or more stirred vessels, or in one or more film evaporators, or in one or more stirred vessels and in one or more film evaporators; wherein the evaporation in the evaporation unit E_1 according to (b) is more preferably carried out in one or more continuous stirred-tank reactors, or in one or more falling film evaporators, or in one or more continuous stirred-tank reactors and in one or more falling film evaporators; wherein the evaporation in the evaporation unit E_1 according to (b) is more preferably carried out in one or more continuous stirred-tank reactors, wherein more preferably, if evaporation in E_1 is carried out in more than one continuous stirred-tank reactors, the continuous stirred-tank reactor are arranged in parallel.

Regarding the purification sub-unit U_D , it is preferred that it comprises at least one distillation column, 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_{VW2} is obtained which is preferably passed to the unit U_W . More preferably, at least a part of at least one stream S_V is passed as heating medium through a heat exchanger of at least one distillation column of U_D , preferably through a heat exchanger of each of the two or three distillation columns of U_D , more preferably through a heat exchanger used for sump evaporation of each of the two or three distillation columns of U_D .

The respectively obtained stream S_{UD} which is obtained from U_D and which is further purified with respect to ϵ -caprolactam is then preferably passed to a crystallization unit U_C from which the final stream S_{CPL} is obtained. Regarding the specific design of the crystallization unit U_C is concerned, no specific restrictions exists. Preferably, at least part of the heat consumed in U_C is at least partially provided by at least one stream S_V , wherein based on S_V , at least one at least partially condensed stream S_{VW3} is obtained which is preferably passed to the unit U_W .

Regarding the recycling according to (vi), it is preferred that (vi) comprises

- (vi.1) feeding the at least one stream S_{VW} , preferably at least one of the one or more streams S_{VW1} , S_{VW2} and S_{VW3} , more preferably at least one of the one or more streams S_{VW11} , S_{VW12} , S_{VW2} and S_{VW3} , more preferably all streams S_{VW1} , S_{VW2} and S_{VW3} , more preferably all

streams S_{VW11} , S_{VW12} , S_{VW2} and S_{VW3} , and the at least one stream S_{RW} , preferably at least one of the one or more streams S_{RW1} and S_{RW2} , more preferably all streams S_{RW1} and S_{RW2} , into a water treatment unit U_W , obtaining from U_W at least one aqueous recycle stream S_W ;
 (vi.2) recycling the at least one aqueous stream S_W at least partially to the reaction unit U_R .

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More preferably, the water treatment unit U_W comprises a water recovery unit U_{WR} and a waste water unit U_{WW} , wherein (vi.1) further comprises

- (vi.1.1) feeding the at least one stream S_{VW} , preferably at least one of the one or more streams S_{VW1} , S_{VW2} and S_{VW3} , more preferably at least one of the one or more streams S_{VW11} , S_{VW12} , S_{VW2} and S_{VW3} , more preferably all streams S_{VW1} , S_{VW2} and S_{VW3} , more preferably all streams S_{VW11} , S_{VW12} , S_{VW2} and S_{VW3} , and the at least one stream S_{RW} , preferably at least one of the one or more streams S_{RW1} and S_{RW2} , more preferably all streams S_{RW1} and S_{RW2} , into the water recovery unit U_{WR} , obtaining from U_{WR} the at least one aqueous recycle stream S_W and at least one aqueous stream S_{SW} ;
 (vi.1.2) feeding the at least one stream S_{SW} to the waste water unit U_{WW} , obtaining from U_{WW} , at least one waste water stream S_{WW} .

According to the present invention, it is preferred that from 91 to 100 weight-%, more preferably from 92 to 100 weight-%, more preferably from 95 to 100 weight-% of S_W consist of water. Prior to being passed into U_R , it is conceivable to suitable pre-treat at least one of the streams S_W , such as by changing the temperature, preferably heating, and/or by changing the pressure, preferably increasing the pressure.

Yet further according to the present invention, it may be preferred that at least one suitable stage, fresh water is added to the process in order to compensate any water losses. Such fresh water can be added, for example, to at least one of the streams and/or directly to the unit U_R .

According to the process of the present invention, it may be preferred that downstream of the reaction unit U_R , at least one solid-liquid separation unit is arranged, wherein preferably at least one of the streams S_L and S_R is passed through at least one solid-liquid separation unit prior to being passed to the next downstream unit. Preferably, such solid-liquid separation unit comprises one or more of a centrifuge, a decanter, a decanter centrifuge, and a filter.

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 U_{PP} , wherein the polyamide 6 produced in U_{PP} is preferably at least partially provided as a feedstock to a textile material producing unit U_{TP} , wherein the textile material M_T produced in U_{TP} is preferably brought onto the market, and wherein, after the life-time T_{MT} of said textile material, it is preferably collected as textile waste material in a textile material collecting unit U_{TC} and preferably suitably provided from U_{TC} to U_R as S_M , preferably via a unit U_M , wherein U_M preferably comprises one or

more silos, and/or one or more hoppers, and/or one or more truck unloading stations, and/or one or more big bag unloading station. Yet further, it is also possible that in the course of producing the textile material in either the unit U_{TP} 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 M_R is also referred to as “textile waste material” in the context of the present invention, and this textile waste material M_R 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 either via the unit U_{TC} and/or the unit U_M . Specifically, according to the present invention, the stream S_M

- 10 - either comprises material M_T and does not comprise M_R ;
- or comprises material M_R and does not comprise material M_T ;
- or comprises material M_T and material M_R .

If desired and /or necessary, and as shown in Fig. 2, one or more streams S_{NCPL} can be additionally passed to U_{PP} , wherein S_{NCPL} comprises non-recycled ϵ -caprolactam, i.e. ϵ -caprolactam from a conventional source. Further, if desired and /or necessary, and as shown in Fig. 2, one or more streams S_{NPA6} can be additionally passed to U_{TP} , wherein S_{NPA6} comprises non-recycled polyamide 6, i.e. polyamide 6 from a conventional source.

- 20 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.

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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.

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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.

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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.

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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 polymeric material, preferably said polyamide 6 as a feedstock for preparing a textile material.

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Further, the present invention relates to the process as described above, which process 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 a textile material producing unit U_{TP} , from which unit U_{TP}

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(A) a textile material M_T is obtained which is brought onto the market, wherein, after the life-time T_{MT} of said textile material M_T , it is at least partially collected as textile waste material

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in a textile material collecting unit U_{TC} ;

(B) remaining material M_R 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 S_M , preferably via U_M .

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Further, the present invention relates to the process as described above, which process 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}

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

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(B) remaining material M_R 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 S_M , preferably via U_M .

5 Downstream of the unit U_{TC} and upstream of the unit U_R , preferably upstream of the unit U_M , 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 optically. If carried out optically, the sorting preferably comprises an infrared
10 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 current separating means. After said sorting, the respectively obtained textile waste material
15 can be subjected to a further treatment, such as cutting and/or milling, prior to being fed to U_R , preferably prior to being fed to U_R via U_M .

Still further, the present invention relates the crystallized ϵ -caprolactam, obtainable or obtained as stream S_{CPL} by a process as described above, wherein said crystallized ϵ -caprolactam exhibits
20 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;
- a purity, determined as described in Reference Example 2, of at least 99.8 weight-%,
25 preferably of at least 99.9 %, more preferably of at least 99.95 %.

Optionally or preferably, said crystallized ϵ -caprolactam exhibits one or more of the following properties:

- an ϵ -caprolactam oligomer content in the range of from 0 to 10 weight-ppm, more
30 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.

35 Optionally or preferably, said crystallized ϵ -caprolactam further exhibits 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
40 of from 0 to 1 weight-ppm.

Optionally or preferably, said crystallized ϵ -caprolactam, in case the solid material M described

above comprises one or more elastanes, exhibits 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;
- 5 - 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;
- 10 - 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.
- 15

Further, the present invention relates to the use of S_{CPL} , obtainable or obtained by a process as described above, for preparing polyamide 6, wherein said use preferably further comprises 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.

- 25 Still further, the present invention 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 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;
 - 30 - 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;
 - 35 - 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;
 - 40 - 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;
- 5 - 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
- 10 - 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.

15 Yet further, the present invention relates to the use of S_{CPL} , obtainable or obtained by a process as described above, preferably of S_{CPL} as described above, for preparing one or more of a polymer and a polymer product; or to 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, preferably of S_{CPL} as described above, as a starting material.

20 Yet further, the present invention relates to said use or said method, 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.

25 Yet further, the present invention relates to said use or said method, 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 any one of embodiments 1 to 14, preferably being S_{CPL} according to any one of embodiments 17 to 20, 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 polyether; at least one polyvinyl chloride; at least natural fiber material such as wool and cotton; at least one cellulose material; at least one natural elastomer; at least one synthetic elastomer; at least one copolymer of two or more of said polymeric compounds including statistical copolymers, gradient copolymers, alternating copolymers, block copolymers, and graft copolymers; and at least one rubber material comprising one or more of at least one natural rubber material and at least one synthetic rubber material.

40 Yet further, the present invention relates to said use or said method, 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.

Yet further, the present invention relates to said use or said method, wherein the polymer, or the polymer product, or the polymer and the polymer product contains or contain polyamide 6, obtainable or obtained from S_{CPL}, said S_{CPL} being obtainable or obtained by a process according to embodiment 28, in an amount of 1 weight-% or more, preferably 2 weight-% or more, more preferably 5 weight-% or more, more preferably 15 weight-% or more, more preferably 30 weight-% or more, more preferably 40 weight-% or more, more preferably 60 weight-% or more, more preferably 80 weight-% or more, more preferably 90 weight-% or more, more preferably 95 weight-% or more; and/or in an amount of 100 weight-% or less, preferably 95 weight-% or less, more preferably 90 weight-% or less, more preferably 50 weight-% or less, more preferably 25 weight-% or less, more preferably 10 weight-% or less.

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 3", 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 and 3". 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 recycling process for recovering ϵ -caprolactam from a solid material M comprising polyamide 6, the process comprising
 - (i) providing a stream S_M comprising the solid material M;
 - (ii) preparing an aqueous depolymerization mixture based on S_M ;
 - (iii) subjecting the depolymerization mixture prepared according to (ii) 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;
 - (iv) 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 ;
 - (v) passing the aqueous stream S_L into a heat-consuming purification unit U_P , obtaining from S_L a stream S_{CPL} comprising ϵ -caprolactam at a concentration c_{SCPL} with $c_{SCPL} \gg c_{SL}$, and further obtaining from S_L one or more aqueous streams S_{RW} , wherein at least part of the heat consumed in U_P is provided by at least one of the one or more streams S_V , thereby obtaining from the at least one stream S_V at least one at least partially condensed aqueous stream S_{VW} ;
 - (vi) 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 .
2. The process of embodiment 1, wherein the solid material M 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 100 weight-%, more preferably from 30 to 100 weight-%, more preferably from 50 to 100 weight-%, more preferably from 80 to 100 weight-%, of M consist of polyamide 6, wherein if the polyamide 6 content of the solid material M is less than 100 weight-%, the solid material M optionally additionally comprises one or more elastanes.

3. The process of embodiment 1 or 2, wherein the recycling according to (vi) comprises
 (vi.1) feeding the at least one stream S_{VW} and the at least one stream S_{RW} into a water
 treatment unit U_W , obtaining from U_W at least one aqueous recycle stream S_W ;
 (vi.2) recycling the at least one aqueous stream S_W at least partially to the reaction unit U_R .
 5
4. The process of embodiment 3, wherein the water treatment unit U_W comprises a water
 recovery unit U_{WR} and a waste water unit U_{WW} , wherein (vi.1) further comprises
 (vi.1.1) feeding the at least one stream S_{VW} and the at least one stream S_{RW} into the water
 recovery unit U_{WR} , obtaining from U_{WR} the at least one aqueous recycle stream S_W
 and at least one aqueous stream S_{SW} ;
 10 (vi.1.2) feeding the at least one stream S_{SW} to the waste water unit U_{WW} , obtaining from
 U_{WW} , at least one waste water stream S_{WW} .
5. The process of any one of embodiments 1 to 4, wherein the purification unit U_P comprises
 one or more of a heat-consuming water separation unit U_{WS} , a heat-consuming distillation
 unit U_D and a heat-consuming crystallization unit U_C , preferably two or more of a heat-
 consuming water separation unit U_{WS} , a heat-consuming distillation unit U_D and a heat-
 consuming crystallization unit U_C , more preferably a heat-consuming water separation unit
 U_{WS} , a heat-consuming distillation unit U_D and a heat-consuming crystallization unit U_C ,
 15 wherein at least part of the heat consumed in one or more of U_{WS} , U_D and U_C is provided by
 at least one of the one or more streams S_V .
 20
6. The process of embodiment 5, comprising one or more of (i-1), (i-2) and (i-3); preferably at
 least two or more of (i-1), (i-2) and (i-3); more preferably (i-1), (i-2) and (i-3):
 25 (i-1) obtaining at least one at least partially condensed aqueous stream S_{VW1} from U_{WS} ;
 (i-2) obtaining at least one at least partially condensed aqueous stream S_{VW2} from U_D ;
 (i-3) obtaining at least one at least partially condensed aqueous stream S_{VW3} from U_C ;
 the process further comprising feeding one or more S_{VW1} , S_{VW2} and S_{VW3} ; preferably two or
 more S_{VW1} , S_{VW2} and S_{VW3} ; more preferably S_{VW1} , S_{VW2} and S_{VW3} into the water treatment
 30 unit U_W as defined in claim 3.
7. The process of embodiment 5 or 6, wherein at least one of the streams S_{RW} is obtained
 from U_{WS} .
8. The process of any one of embodiments 1 to 7, wherein the purification unit U_P comprises a
 heat-consuming water separation unit U_{WS} , a heat-consuming distillation unit U_D and a heat-
 consuming crystallization unit U_C , the process comprising feeding the stream S_L comprising
 ϵ -caprolactam at a concentration c_{SL} to U_{WS} , obtaining from U_{WS} a stream U_{WS} comprising ϵ -
 ϵ -caprolactam at a concentration c_{UWS} , feeding the stream S_{UWS} to the distillation unit U_D ,
 35 obtaining from U_D a stream S_{UD} comprising ϵ -caprolactam at a concentration c_{UD} , and
 feeding the stream S_{UD} into the crystallization unit U_C , and obtaining from U_C a stream S_{CPL}
 40 comprising ϵ -caprolactam at a concentration c_{SCPL} , wherein $c_{SL} < c_{UWS} < c_{UD} < c_{SCPL}$.

9. The process of any one of embodiments 1 to 8, wherein the water separation unit U_{WS} comprises at least two heat-consuming water separation sub-units U_{WS1} and U_{WS2} , preferably two serially coupled heat-consuming water separation sub-units U_{WS1} and U_{WS2} ,
5 wherein the stream S_L is fed into U_{WS1} and wherein at least part of the heat consumed in one or more of U_{WS1} and U_{WS2} is provided by at least one of the one or more streams S_V .
10. The process of embodiment 9, comprising one or more of (ii-1) and (ii-2) preferably (ii-1) and (ii-2):
10 (ii-1) obtaining at least one at least partially condensed aqueous stream S_{VW11} from U_{WS1} ;
(ii-2) obtaining at least one at least partially condensed aqueous stream S_{VW12} from U_{WS2} .
11. The process of embodiment 10, wherein at least one aqueous stream S_{RW1} is obtained from U_{WS1} and at least one aqueous stream S_{RW2} is obtained from U_{WS2} , and wherein at least one
15 of S_{RW1} and S_{RW2} , preferably S_{RW1} and S_{RW2} are fed into U_W .
12. The process of any one of embodiments 9 to 11, wherein downstream of U_{WS1} and upstream of U_{WS2} , a separation unit U_I is located, the process comprising obtaining from U_{WS1} an aqueous stream S_{UWS1} , feeding the stream S_{UWS1} into the separation unit U_I ,
20 obtaining from U_I an aqueous stream S_{UI} , and feeding the stream S_{UI} into the unit U_{WS2} , wherein in U_I , one or more of impurities are separated from S_{UWS1} , thereby obtaining from U_I an impurity stream S_I , said impurities preferably comprising at least one impurity comprised in S_R according to (ii).
- 25 13. The process of any one of embodiments 1 to 12, wherein the evaporation unit U_E comprises two or more evaporation sub-units, the process comprising obtaining at least two vapor streams S_{V1} and S_{V2} , passing the vapor stream S_{V1} to at least one heat-consuming unit and passing the vapor stream S_{V2} to at least one heat-consuming unit, wherein the vapor streams S_{V1} and S_{V2} differ from each other in either pressure and/or temperature.
30
14. The process of any one of embodiments 1 to 13, wherein downstream of U_R , at least one solid-liquid separation unit is arranged, wherein preferably at least one of the streams S_L and S_R is passed through at least one solid-liquid separation unit prior to being passed to the next downstream unit.
35
15. The process of any one of embodiments 1 to 14, 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}
40 (A) a textile material M_T is obtained which is brought onto the market, wherein, after the life-time T_{MT} of said textile material M_T , it is at least partially collected as textile waste material in a textile material collecting unit U_{TC} ;

- (B) remaining material M_R 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 S_M , preferably via U_M .
16. The process of any one of embodiments 1 to 14, 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}
- (A) an engineering plastics material M_T is obtained which is brought onto the market, wherein, after the life-time T_{MT} of said engineering plastics material M_T , it is at least partially collected as engineering plastics waste material in an engineering plastics material collecting unit U_{TC} ;
- (B) remaining material M_R 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 S_M , preferably via U_M .
17. Crystallized ϵ -caprolactam, obtainable or obtained as stream S_{CPL} by a process according to any one of embodiments 1 to 14, 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;
 - 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 %.
18. The crystallized ϵ -caprolactam of embodiment 17, 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.
19. The crystallized ϵ -caprolactam of embodiment 17 or 18, 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.

20. The crystallized ϵ -caprolactam of any one of embodiments 17 to 19, preferably wherein the solid material M as defined in embodiment 2 comprises one or more elastanes, said crystallized ϵ -caprolactam exhibiting one or more of the following properties:
- 5 - 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;
 - 10 - 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
 - 15 - 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.
 - 20
21. Use of S_{CPL} , obtainable or obtained by a process according to any one of embodiments 1 to 15, preferably of S_{CPL} according to any one of embodiments 17 to 20, for preparing
- 25 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.
22. Use of a process according to any one of embodiments 1 to 14 for preparing high-purity ϵ -caprolactam from a solid material M, preferably from 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:
- 30 - 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;
 - 35 - 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;
 - 40

- 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.
23. Use of S_{CPL} , obtainable or obtained by a process according to any one of embodiments 1 to 14, preferably of S_{CPL} according to any one of embodiments 17 to 20, 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 any one of embodiments 1 to 14, preferably of S_{CPL} according to any one of embodiments 17 to 20, as a starting material.
24. The use or the method of embodiment 23, 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.
25. The use or the method of embodiment 23 or 24, 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 any one of embodiments 1 to 14, preferably being S_{CPL} according to any one of embodiments 17 to 20, 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 polyether; at least one polyvinyl chloride; at least natural fiber material such as wool and cotton; at least one cellulose material; at least one natural elastomer; at least one synthetic elastomer; at least one copolymer of two or more of said polymeric compounds including statistical copolymers, gradient copolymers, alternating copolymers, block copolymers, and graft

copolymers; and at least one rubber material comprising one or more of at least one natural rubber material and at least one synthetic rubber material.

26. The use or the method of any one of embodiments 23 to 25, 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.
27. The use or the method of any one of embodiments 23 to 26, 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

5 according to embodiment 28, in an amount of 1 weight-% or more, preferably 2 weight-% or more, more preferably 5 weight-% or more, more preferably 15 weight-% or more, more preferably 30 weight-% or more, more preferably 40 weight-% or more, more preferably 60 weight-% or more, more preferably 80 weight-% or more, more preferably 90 weight-% or more, more preferably 95 weight-% or more; and/or in an amount of 100 weight-% or less, preferably 95 weight-% or less, more preferably 90 weight-% or less, more preferably 50 weight-% or less, more preferably 25 weight-% or less, more preferably 10 weight-% or less.

10 As far as the embodiment 27 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 23 to 27 are concerned, preparing the polymer, the polymer product, or the polymer and the
15 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,
20 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“.

25

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.

30 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,
35 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 holder and, thus, is an end-of-life material for said holder.

40

The term "engineering plastics" as used herein refers to high-performance plastics grades which possess physical properties enabling them to perform for prolonged use in structural applications,

over a wide temperature range, under mechanical stress, and in difficult chemical and physical environments used for example to fabricate plastic parts replacing traditional engineering materials like metals and ceramics. Engineering plastics specifically apply in the fabrication of mechanical parts across several industries such as automotive, medical, electrical and electronics, aerospace, construction and consumer products. The term “engineering plastics waste material” as used herein covers an engineering plastics material as defined above, the inherent value of which has been consumed from the perspective of its current holder and, thus, is an end-of-life material for said holder.

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

The present invention is illustrated by the following figures and reference examples.

25 Short description of the figures

List of abbreviations

Units

- 30 U_M Unit for providing feed stream S_M
 U_R Reaction / depolymerisation unit
 U_E Evaporation unit
 U_P Purification unit
 35 U_W Water treatment unit
 U_{WR} Water recovery unit
 U_{WW} Waste water unit
 U_{WS} Water separation unit
 U_{WS1} Upstream water separation unit
 40 U_{WS2} Downstream water separation unit
 U_I Intermediate separation
 U_D Distillation unit

U_C	Crystallization unit
U_{PP}	PA6 material production unit
U_{TP}	Textile material production unit
U_{TC}	Textile material collection unit

5

Streams

	S_M	PA6 waste material stream
	S_R	Product stream obtained from depolymerisation
10	S_L	Liquid stream obtained from evaporation unit comprising CPL (ϵ -caprolactam)
	S_{CPL}	Final solid CPL product
	S_V	One or more aqueous vapour streams obtained from evaporation unit
	S_{V1}	Aqueous vapour stream obtained from evaporation unit
	S_{V2}	Aqueous vapour stream obtained from evaporation unit
15	S_{VW}	One or more at least partially condensed streams obtained from S_V
	S_{VW1}	Condensed stream obtained from U_{WS}
	S_{VW11}	Condensed stream obtained from U_{WS1}
	S_{VW12}	Condensed stream obtained from U_{WS2}
	S_{VW2}	Condensed stream obtained from U_D
20	S_{VW3}	Condensed stream obtained from U_C
	S_{RW}	One or more aqueous streams (reaction water streams)
	S_{RW1}	Aqueous streams obtained from U_{WS1}
	S_{RW2}	Aqueous streams obtained from U_{WS2}
	S_W	Recycle water stream obtained from water removal unit U_{WR}
25	S_{SW}	Stream separated in U_{WR} to be passed to waste water system U_{WW}
	S_{WW}	Waste water stream
	S_{UWS}	CPL containing stream, obtained from water separation unit U_{WS}
	S_{UWS1}	CPL containing stream, obtained from water separation sub-unit U_{WS1}
	S_{UWS2}	CPL containing stream, obtained from water separation sub-unit U_{WS2}
30	S_{UI}	CPL containing stream, obtained from impurity separation unit U_I
	S_{UD}	CPL containing stream, obtained from distillation unit U_D
	S_I	Stream comprising impurities, obtained from U_I
	S_{NCPL}	Non-recycle CPL stream
	S_{NPA6}	Non-recycle PA6 stream

35

Others

	T_{MT}	Lifetime of textile material M_T
	M_T	Textile material produced in U_{TP}
40	M_R	Material comprising polyamide 6, remaining from production in U_{TP}

Figure 1 shows a process according to present invention

According to this process, a waste material stream S_M comprising polyamide 6 is passed into reaction unit U_R where the waste material is subjected to polyamide 6 depolymerization conditions (depolymerisation via hydrolysis in an aqueous medium). From the reaction unit U_R , a liquid aqueous stream S_R is obtained and removed which comprises ϵ -caprolactam and one or more impurities. This stream S_R is then passed to an evaporation unit U_E from which a liquid aqueous stream S_L and one or more aqueous vapor streams S_V are obtained and removed; in Fig. 1, only one vapor stream S_V is shown. The stream S_L has a higher ϵ -caprolactam concentration than the stream S_R . The stream S_L is then passed to a heat-consuming purification unit U_P where a further purification with regard to ϵ -caprolactam occurs. From the stream S_L which is fed into U_P , a product stream S_{CPL} is finally obtained which comprises ϵ -caprolactam at a concentration which is significantly higher than the ϵ -caprolactam concentration of the stream S_L . According to the process of the present invention, at least a part of the heat consumed in the purification unit U_P is at least partially provided by at least one of the one or more vapor streams S_V and based on S_V , one or more at last partially condensed aqueous streams S_{VW} are obtained and removed from U_P ; only one stream S_{VW} is shown in Fig. 1. Yet further from the purification unit U_P , one or more aqueous streams S_{RW} are obtained from S_L . At least one stream S_{VW} is then at least partially recycled to the reaction unit U_R , and also at least one stream S_{RW} is at least partially recycled to the reaction unit U_R .

Figure 2 shows a process including the complete recycling loop

The process according to Fig. 2 shows the further use of the stream S_{CPL} , i.e. the purified ϵ -caprolactam. According to the present invention, stream S_{CPL} is passed to a polyamide 6 production unit U_{PP} where it is employed as starting material. If need be, one or more further streams S_{NCPL} can be additionally passed to U_{PP} , said streams comprising non-recycled ϵ -caprolactam, i.e. ϵ -caprolactam from a conventional source. The respectively prepared polyamide 6 material is then passed to a unit U_{TP} where it is used as a starting material for preparing a material comprising polyamide 6, preferably a textile material comprising polyamide 6. If need be, one or more further streams S_{NPA6} can be additionally passed to U_{TP} , said streams comprising non-recycled polyamide 6, i.e. polyamide 6 from a conventional source. Depending on the type of material prepared in U_{TP} , also further streams comprising one or more starting materials other than polyamide 6 can be passed to U_{TP} . The material, preferably the textile material M_T obtained from U_{TP} then goes into the market and remains there for a given lifetime T_{MT} . Thereafter, the respective end-of-life material is suitably collected in a collecting unit U_{TC} , preferably a textile material collecting unit, from which it is suitably passed as stream the S_M or as part of the stream S_M to the reaction unit U_R preferably via a unit U_M for providing the stream S_M to U_R . Such unit U_M usually comprises any apparatus by which the preferably solid material M can be suitably passed to the reaction unit U_R . Preferably, U_M comprises apparatuses such as one or more silos, one or more hoppers, one or more truck unloading stations, one or more big bag unloading station, and the like. Further in Fig. 2, it is shown that in the production unit U_{TP} ,

remaining material M_R is obtained from the production process, i.e. material which is not comprised in M_T . By way of example, M_R may be in the form textile cuttings. This material can be fed, either via U_{TC} and/or directly via U_M , to U_R as the stream S_M or as part of stream S_M . This recycle loop as shown in Fig. 2 also applies to any of Figs. 3 to 6 below, however, is not explicitly shown there.

Figure 3 shows a process with a preferred water treatment stage

The process as shown in this Fig. 3 shows a preferred treatment of the streams S_{VW} and S_{RW} as already shown in Figs. 1 and 2. According to this process, the streams S_{VW} and S_{RW} are passed into a water treatment unit U_W from which a stream S_W is obtained which is then (at least partially) recycled as aqueous stream S_W (or part thereof) to the reaction unit U_R . Further from U_W , one or more waste water streams S_{WW} are obtained which are not recycled to the process. Preferably, the water treatment unit U_W comprises a water recovery unit U_{WR} and optionally a waste water unit U_{WW} . Preferably, the streams S_{VW} and S_{RW} are passed into the water treatment unit U_W where they are suitably purified and/or suitably collected in order to obtain the one or more aqueous recycle streams. Streams which are obtained from such purification may then be passed to the waste water treatment unit U_{WW} .

Figure 4 shows a process with a preferred heat-consuming purification unit U_P

The process as shown in Fig. 4 shows a preferred way of purifying the stream S_L with respect to ϵ -caprolactam. According to this process, the stream S_L is first passed to a water separation unit from which the one or more streams S_{RW} are obtained which are then preferably passed to the water treatment unit U_W as already shown in Fig. 2 and, according to a preferred design, in Fig. 3. Further, at least one of the streams S_V is passed to U_{WS} for at least partially meeting the heat demand of U_{WS} ; based on this at least one stream S_V passed to U_{WS} , one or more at least partially condensed streams S_{VW1} are obtained and preferably further passed to the water treatment U_W . The stream S_{UWS} comprising ϵ -caprolactam is then preferably passed to a distillation unit U_D for further purification with respect to ϵ -caprolactam. Further, at least one of the streams S_V is passed to U_D for at least partially meeting the heat demand of U_D ; based on this at least one stream S_V passed to U_D , one or more at least partially condensed streams S_{VW2} are obtained and preferably further passed to the water treatment U_W . The stream S_{UD} comprising ϵ -caprolactam is then preferably passed to a crystallization unit U_C for further purification with respect to ϵ -caprolactam. Further, at least one of the streams S_V is passed to U_C for at least partially meeting the heat demand of U_C ; based on this at least one stream S_V passed to U_C , one or more at least partially condensed streams S_{VW3} are obtained and preferably further passed to the water treatment U_W .

Figure 5 shows a process with a preferred water separation unit U_{WS}

The process as shown in Fig. 5 shows a preferred way of separating water from the stream S_L in

the water separation unit U_{WS} . According to this process, the stream S_L is first passed to a first stage of water separation, carried out in the unit U_{WS1} . From U_{WS1} , a stream comprising ϵ -caprolactam is then passed to an intermediate treatment stage U_I where impurities may be removed. The thus purified stream obtained from U_I is then further passed to a second stage of water separation, carried out in the unit U_{WS2} . From said unit U_{WS2} , a stream S_{UWS2} comprising ϵ -caprolactam is obtained which corresponds to the stream S_{UWS} as shown in Fig. 4 and which is then preferably passed to the distillation unit U_D . From the intermediate unit U_I , a stream S_I comprising the respectively separated impurities is removed which, depending on the amount and/or the chemical nature of the impurities, may be put to further use. According to this process, one or more aqueous streams S_{RW1} are obtained which are then preferably passed to the water treatment unit U_W as already shown in Fig. 2 and, according to a preferred design, in Fig. 3. Further according to this process, one or more aqueous streams S_{RW2} are obtained which are then preferably passed to the water treatment unit U_W as already shown in Fig. 2 and, according to a preferred design, in Fig. 3. Preferably, at least one of the streams S_V is passed to U_{WS1} for at least partially meeting the heat demand of U_{WS1} ; based on this at least one stream S_V passed to U_{WS1} , one or more at least partially condensed streams S_{VW11} are obtained and preferably further passed to the water treatment U_W . Preferably, at least one of the streams S_V is passed to U_{WS2} for at least partially meeting the heat demand of U_{WS2} ; based on this at least one stream S_V passed to U_{WS2} , one or more at least partially condensed streams S_{VW12} are obtained and preferably further passed to the water treatment U_W .

Figure 6 shows a process with a preferred use of different vapour streams S_V

The process as shown in Fig. 6 shows, based on the preferred process design according to Fig. 5, a further preferred way of providing heat to the purification unit U_P . According to this process, one or more vapour streams S_{V1} and one or more vapour streams S_{V2} are obtained from the evaporation unit U_E which, for example, may comprise two or more evaporation sub-units (not shown), wherein the one or more streams S_{V1} have pressures and temperatures which differ from the pressures and temperatures of the streams S_{V2} . Accordingly, the streams S_{V1} and S_{V2} can be used for providing heat to units with different heat demands. By way of example and as shown in Fig. 6, the streams S_{V1} are used for providing at least part of the heat consumed by U_{WS1} and U_C whereas the streams S_{V2} are used for providing at least part of the heat consumed by U_{WS2} and U_D . Accordingly, based on the streams S_{V1} , one or more at least partially condensed streams S_{VW11} and S_{VW3} are obtained and preferably further passed to the water treatment U_W . Further accordingly, based on the streams S_{V2} , one or more at least partially condensed streams S_{VW12} and S_{VW2} are obtained and preferably further passed to the water treatment U_W .

Reference Examples

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 $f = 150$.

- 5 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 ($\text{CoCl}_2 \cdot 6 \text{H}_2\text{O}$) and 1.245 g potassium hexachloroplatinate(IV) (K_2PtCl_6) are dissolved in 100 ml hydrochloric acid
10 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.

- 15 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 $\lambda =$
20 390 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.

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

The purity of the crystallized ϵ -caprolactam and the respective amounts of impurities was determined via GC-FID/MS using GC (Agilent 7890A) coupled with two MSDs (Agilent 5975C) for electron impact ionisation and chemical ionisation.

- 30 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. Due to the finding that the process of the present leads to S_{CPL} compositions
35 containing other impurities only at very low weight-ppm values, these other impurities could be neglected as far as the calculation of the purity of crystallized ϵ -caprolactam is concerned.

- The respective are-% values obtained from the measurement was extrapolated to the respective weight-% / weight-ppm values as follows: the diol compounds mentioned above are calibrated in
40 the GC and then measured quantitatively, i.e. in weight-%. By subtracting these measured weight-% values from 100 weight-%, the purity of the crystallized S_{CPL} is obtained.

Claims

1. A recycling process for recovering ϵ -caprolactam from a solid material M comprising polyamide 6, the process comprising
 - (i) providing a stream S_M comprising the solid material M;
 - 5 (ii) preparing an aqueous depolymerization mixture based on S_M ;
 - (iii) subjecting the depolymerization mixture prepared according to (ii) 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;
 - 10 (iv) 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 ;
 - (v) passing the aqueous stream S_L into a heat-consuming purification unit U_P , obtaining
 - 15 from S_L a stream S_{CPL} comprising ϵ -caprolactam at a concentration c_{SCPL} with $c_{SCPL} \gg c_{SL}$, and further obtaining from S_L one or more aqueous streams S_{RW} , wherein at least part of the heat consumed in U_P is provided by at least one of the one or more streams S_V , thereby obtaining from the at least one stream S_V at least one at least partially condensed aqueous stream S_{VW} ;
 - 20 (vi) 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 .
2. The process of claim 1, wherein the solid material M comprises, more preferably consists of, waste material, wherein said waste material more preferably comprises, more preferably
 - 25 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 100 weight-%, more preferably from 30 to 100 weight-%, more preferably from 50 to 100 weight-%, more preferably from 80 to 100 weight-%, of M consist of polyamide 6, wherein if the polyamide 6 content of the solid
 - 30 material M is less than 100 weight-%, the solid material M optionally additionally comprises one or more elastanes.
3. The process of claim 1 or 2, wherein the recycling according to (vi) comprises
 - (vi.1) feeding the at least one stream S_{VW} and the at least one stream S_{RW} into a water
 - 35 treatment unit U_W , obtaining from U_W at least one aqueous recycle stream S_W ;
 - (vi.2) recycling the at least one aqueous stream S_W at least partially to the reaction unit U_R .
4. The process of claim 3, wherein the water treatment unit U_W comprises a water recovery unit U_{WR} and a waste water unit U_{WW} , wherein (vi.1) further comprises
 - 40 (vi.1.1) feeding the at least one stream S_{VW} and the at least one stream S_{RW} into the water recovery unit U_{WR} , obtaining from U_{WR} the at least one aqueous recycle stream S_W and at least one aqueous stream S_{SW} ;

- (vi.1.2) feeding the at least one stream S_{SW} to the waste water unit U_{WW} , obtaining from U_{WW} , at least one waste water stream S_{WW} .
5. The process of any one of claims 1 to 4, wherein the purification unit U_P comprises one or more of a heat-consuming water separation unit U_{WS} , a heat-consuming distillation unit U_D and a heat-consuming crystallization unit U_C , preferably two or more of a heat-consuming water separation unit U_{WS} , a heat-consuming distillation unit U_D and a heat-consuming crystallization unit U_C , more preferably a heat-consuming water separation unit U_{WS} , a heat-consuming distillation unit U_D and a heat-consuming crystallization unit U_C , wherein at least part of the heat consumed in one or more of U_{WS} , U_D and U_C is provided by at least one of the one or more streams S_V ;
wherein the process preferably further comprises one or more of (i-1), (i-2) and (i-3); more preferably at least two or more of (i-1), (i-2) and (i-3); more preferably (i-1), (i-2) and (i-3):
(i-1) obtaining at least one at least partially condensed aqueous stream S_{VW1} from U_{WS} ;
(i-2) obtaining at least one at least partially condensed aqueous stream S_{VW2} from U_D ;
(i-3) obtaining at least one at least partially condensed aqueous stream S_{VW3} from U_C ;
the process preferably further comprising feeding one or more S_{VW1} , S_{VW2} and S_{VW3} ;
preferably two or more S_{VW1} , S_{VW2} and S_{VW3} ; more preferably S_{VW1} , S_{VW2} and S_{VW3} into the water treatment unit U_W as defined in claim 3.
6. The process of claim 5, wherein at least one of the streams S_{RW} is obtained from U_{WS} .
7. The process of any one of claims 1 to 6, wherein the purification unit U_P comprises a heat-consuming water separation unit U_{WS} , a heat-consuming distillation unit U_D and a heat-consuming crystallization unit U_C , the process comprising feeding the stream S_L comprising ϵ -caprolactam at a concentration c_{SL} to U_{WS} , obtaining from U_{WS} a stream U_{WS} comprising ϵ -caprolactam at a concentration c_{UWS} , feeding the stream S_{UWS} to the distillation unit U_D , obtaining from U_D a stream S_{UD} comprising ϵ -caprolactam at a concentration c_{UD} , feeding the stream S_{UD} into the crystallization unit U_C , and obtaining from U_C a stream S_{CPL} comprising ϵ -caprolactam at a concentration c_{SCPL} , wherein $c_{SL} < c_{UWS} < c_{UD} < c_{SCPL}$.
8. The process of any one of claims 1 to 7, wherein the water separation unit U_{WS} comprises at least two heat-consuming water separation sub-units U_{WS1} and U_{WS2} , preferably two serially coupled heat-consuming water separation sub-units U_{WS1} and U_{WS2} , wherein the stream S_L is fed into U_{WS1} and wherein at least part of the heat consumed in one or more of U_{WS1} and U_{WS2} is provided by at least one of the one or more streams S_V .
9. The process of claim 8, comprising one or more of (ii-1) and (ii-2) preferably (ii-1) and (ii-2):
(ii-1) obtaining at least one at least partially condensed aqueous stream S_{VW11} from U_{WS1} ;
(ii-2) obtaining at least one at least partially condensed aqueous stream S_{VW12} from U_{WS2} .

10. The process of claim 9, wherein at least one aqueous stream S_{RW1} is obtained from U_{WS1} and at least one aqueous stream S_{RW2} is obtained from U_{WS2} , and wherein at least one of S_{RW1} and S_{RW2} , preferably S_{RW1} and S_{RW2} are fed into U_W .
- 5 11. The process of any one of claims 8 to 10, wherein downstream of U_{WS1} and upstream of U_{WS2} , a separation unit U_I is located, the process comprising obtaining from U_{WS1} an aqueous stream S_{UWS1} , feeding the stream S_{UWS1} into the separation unit U_I , obtaining from U_I an aqueous stream S_{UI} , and feeding the stream S_{UI} into the unit U_{WS2} , wherein in U_I , one or more of impurities are separated from S_{UWS1} , thereby obtaining from U_I an impurity stream S_I , said impurities preferably comprising at least one impurity comprised in S_R according to (ii).
- 10 12. The process of any one of claims 1 to 11, wherein the evaporation unit U_E comprises two or more evaporation sub-units, the process comprising obtaining at least two vapor streams S_{V1} and S_{V2} , passing the vapor stream S_{V1} to at least one heat-consuming unit and passing the vapor stream S_{V2} to at least one heat-consuming unit, wherein the vapor streams S_{V1} and S_{V2} differ from each other in either pressure and/or temperature.
- 15 13. The process of any one of claims 1 to 12, 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}
- 20 (A) textile material M_T is obtained which is brought onto the market, wherein, after the lifetime T_{MT} of said textile material M_T , it is at least partially collected as textile waste material in a textile material collecting unit U_{TC} ;
- 25 (B) remaining material M_R 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 S_M , preferably via a feeding unit U_M .
- 30 14. Crystallized ϵ -caprolactam, obtainable or obtained as stream S_{CPL} by a process according to any one of claims 1 to 12, exhibiting one or more of the following properties:
- 35 - an APHA color 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 of at least 99.8 weight-%, preferably of at least 99.9 %, more preferably of at least 99.95 %;
- and preferably exhibiting one or more of the following properties:
- 40 - 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;
- 5 and preferably further exhibiting one or more of the following properties, more preferably wherein the solid material M as defined in claim 2 comprises one or more elastanes:
- 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; 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.
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- 25 15. Use of S_{CPL} , obtainable or obtained by a process according to any one of claims 1 to 12, preferably of S_{CPL} according to claim 14, 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.