

METHOD FOR RECYCLING PLASTICS BY DISSOLUTION AND OPTIMIZED POLYMER-SOLVENT SEPARATION

TECHNICAL FIELD

The present invention relates to a process for purifying and recycling plastics, in particular used plastics, in order to obtain a stream of purified thermoplastic polymers which can be upgraded, for example in the manufacture of new plastic articles. More particularly, the present invention concerns a process for treating a plastic feedstock, in particular obtained from plastic waste, comprising thermoplastics and in particular polyolefins, for example polyethylene and/or polypropylene, by dissolving the targeted thermoplastics in a solvent and purifying the polymer solution obtained, followed by polymer-solvent separation using a succession of gas-liquid separation sections operated under particular conditions. Said process thus makes it possible, after purification of the polymer solution, to separate the dissolution solvent used from the polymer stream in a simple but highly efficient manner and thus to recover a stream of purified thermoplastics with very low residual solvent contents.

PRIOR ART

Plastics obtained from collection and sorting channels can be upgraded according to various channels.

“Mechanical” recycling makes it possible to partly reuse certain waste either directly in new articles or by mixing the streams of mechanically sorted plastic waste with streams of virgin polymers. This type of upgrading is limited since, although it makes it possible to obtain a plastic stream concentrated in a particular type of polymer, mechanical sorting does not make it possible to remove the impurities that are at least partly trapped in the polymer matrix, for instance the additives, such as the fillers, colorants, pigments, plasticizers and metals. Indeed, additives are compounds conventionally introduced into polymer formulations to give the material, and thus the final articles, the desired properties, for example high mechanical strength, a particular colour, etc.

“Chemical” recycling is primarily directed towards eliminating the additives and, depending on the processes applied, chemically modifying the macromolecular chains of the polymers under consideration to a greater or lesser extent (for example recovering the intact polymer, depolymerizing it or non-selectively breaking the chains of various polymers to obtain mixtures of compounds comprising carbon and hydrogen). These various chemical recycling options involve sequences of steps that are generally complex. For example, plastic waste may undergo a pyrolysis step and the pyrolysis oil recovered, generally after purification, may be at least partly converted, for example, into olefins by steam cracking. These olefins

can then be polymerized or transformed into monomers before being polymerized. This type of sequence may be suitable for feedstocks that have undergone little sorting or for sorting centre rejects, but it generally requires significant energy consumption in particular due to the high-temperature treatments.

5 Another route for recycling plastic waste consists in reformulating plastic materials, based on thermoplastics, in particular polyolefins such as (co)polypropylenes and (co)polyethylenes, which appears to be more virtuous. Specifically, this route for recycling plastic waste consists in dissolving the targeted polymer in a solvent and in eliminating the impurities, for example additives such as fillers, colorants, pigments, plasticizers and metals and/or polymers from
10 the feedstock other than the one(s) under consideration, without modifying the macromolecular chains of the targeted polymer. Conserving the polymer structure reduces the effort to be expended and explains the good performance of this recycling approach, in particular in terms of energy consumption.

Several studies thus present various methods for treating plastic waste by dissolution and
15 purification.

Document US 2017/002110 describes a particular method for purifying a polymer feedstock in particular obtained from plastic waste, by dissolving the polymer in a solvent, under particular temperature and pressure conditions, followed by placing the polymer solution obtained in contact with a solid. The method described in patent application US 2017/002110
20 finally comprises a step of separating the purified polymer from the solvent under temperature and pressure conditions in which said polymer precipitates.

Document WO 2018/114047 proposes, for its part, a method for selectively dissolving a particular polymer of a plastic in a solvent at a dissolution temperature close to the boiling point of the solvent. The polymer solution is then centrifuged and the polymer is
25 subsequently separated from the solvent, for example by flashing.

Document WO 2018/118579 describes a method for purifying a polymer feedstock in particular obtained from plastic waste by dissolving the polymer in a solvent in a stirred reactor, followed by a sedimentation step. More particularly, WO 2018/118579 illustrates the purification of a feedstock composed of post-consumer polypropylene by dissolving it in n-
30 butane in an autoclave stirred at 140°C and 900 psig (6.21 MPa), followed by a sedimentation phase after stopping the stirring in the autoclave. The polymer solution obtained is optionally passed through beds of solids and then depressurized so as to be able to separate at least some of the butane solvent from the polypropylene.

The present invention is directed towards improving these processes for treating
35 thermoplastics by dissolution in a solvent and in particular the separation of the solvent used

from the purified polymer. In particular, the present invention seeks, in a process for purifying a plastic feedstock comprising thermoplastics by dissolution in a solvent, to optimize the separation of solvents, in particular of the dissolution solvent used, from said purified thermoplastics, so as to recover a stream of thermoplastics, in particular polyolefins, which is purified and in particular decolourized and deodourized, and which has a very low residual solvent content, preferably less than or equal to 5% by weight. The present invention seeks most particularly to separate purified thermoplastics, preferably purified polyolefins, efficiently and simply from the solvent in which they are dissolved.

SUMMARY OF THE INVENTION

- 10 The invention relates to a process for treating a plastic feedstock comprising thermoplastics, said process comprising:
- a) a step of dissolving the plastic feedstock in a dissolution solvent, step a) being performed at a dissolution temperature of between 100°C and 300°C and at a dissolution pressure of between 0.1 and 100.0 MPa absolute, to obtain at least one crude polymer solution;
 - 15 b) a step of purifying the crude polymer solution to obtain a purified polymer solution, comprising:
 - b1) a sub-step of separating out the insoluble matter; and/or
 - b2) a sub-step of washing, by contact with a dense solution; and/or
 - b3) a sub-step of extraction, by contact with an extraction solvent; and/or
 - 20 b4) a sub-step of adsorption of the impurities by contact with an adsorbent; and then
 - c) a step of solvent-polymer separation of the purified polymer solution, to obtain a stream of purified thermoplastic polymers and at least one solvent stream, wherein said solvent-polymer separation step c) implements a gas-liquid separation section or a plurality of gas-liquid separation sections operating in series,
 - 25 wherein said gas-liquid separation section or each of the gas-liquid separation sections is operated at an inlet temperature of between 100°C and 300°C, and at a pressure lower than the pressure at the outlet of step b), wherein, when step c) implements a plurality of gas-liquid separation sections, the pressure of the subsequent section is lower than that of the preceding section,
 - 30 wherein the purified polymer solution, obtained from the purification step b), feeds into said gas-liquid separation section or into the first gas-liquid separation section of the series, said gas-liquid separation section or each of the gas-liquid separation sections producing a gaseous effluent, which corresponds to said at least one solvent stream, and a liquid effluent, wherein, when step c) implements a plurality of gas-liquid separation sections, the liquid
 - 35 effluent from the preceding section feeds into the subsequent section,

the liquid effluent from said gas-liquid separation section or from the last gas-liquid separation section of the series constituting said stream of purified thermoplastic polymers.

Said at least one solvent stream advantageously comprises the solvent(s) used in the process. In particular, it comprises dissolution solvent and optionally extraction solvent and/or dense solution.

The advantage of the process according to the invention is that it proposes a process for the recycling, via dissolution, of thermoplastics, preferably polyolefins, such as polypropylene, polyethylene, copolymers thereof, or mixtures thereof, included in a plastic feedstock and in particular in plastic waste, for example post-consumer waste, allowing the recovery of a stream of purified thermoplastics, i.e. stripped of at least some of the impurities contained in the plastic feedstock, and having a very low residual solvent content, in particular less than or equal to 5% by weight, preferably less than or equal to 1.00% by weight, preferably less than or equal to 0.10% by weight, preferentially less than or equal to 500 ppm by weight of solvent relative to the total weight of the stream of purified thermoplastics. The recycling process according to the invention, which is based on the principle of dissolving the targeted thermoplastics and purifying the polymer solution obtained, has the advantage, in addition to eliminating at least some of the organic and inorganic impurities contained in the plastic feedstock, for example the additives introduced into the polymer materials by the formulators, of proposing a simple and effective scheme for separating the thermoplastics, stripped of impurities, from the solvent of the polymer solution, in particular from the dissolution solvent used.

Thus, the process according to the invention has the advantage of proposing a simple process for recycling thermoplastics, and in particular polyolefins, such as polypropylene, polyethylene, copolymers thereof, or mixtures thereof, included in a plastic feedstock, for example from post-consumer waste, with an optimized solvent-polymer separation step, so as to obtain a stream of thermoplastics, in particular polyolefins, which is purified and in particular decolourized and deodourized, having sufficiently low residual impurity and solvent contents so that the purified thermoplastics may be used in any type of plastic formulation in place of virgin resin. In particular, the process according to the invention makes it possible to recover a stream of purified thermoplastics, in particular a stream of purified polyolefins or even polypropylene or polyethylene, comprising at most 5% by weight of impurities, very advantageously at most 1.0% by weight of impurities, preferentially at most 0.5% by weight of impurities, relative to the total weight of the stream of purified thermoplastics.

The invention also has the advantage of participating in the recycling of plastics and in conserving fossil resources, by enabling the upgrading of plastic waste. Specifically, it allows

the purification of plastic waste for the purpose of obtaining a stream of purified thermoplastic polymers, in particular purified polyolefins, or even purified polypropylene or polyethylene, with a reduced content of impurities, in particular a decolourized and deodourized stream, which may be reused to form new plastic articles. The purified thermoplastics obtained may thus be used directly in formulations as a mixture with additives, for example plasticizers, colorants, pigments, fillers, etc., in place of or as a mixture with virgin resins, for the purpose of obtaining plastic materials having aesthetic, mechanical or rheological working properties which facilitate their reuse and the upgrading thereof.

The present invention also relates to a device for treating a plastic feedstock to obtain a stream of purified thermoplastic polymers, said device comprising:

- dissolution means for bringing into contact and at least partially dissolving the plastic feedstock in a dissolution solvent, and obtaining a crude polymer solution;
- purification means for purifying the crude polymer solution and obtaining a purified polymer solution;

- a solvent-polymer separation device, located downstream of said purification means, for separating the purified polymer solution into a stream of purified thermoplastic polymers and at least one solvent effluent,

characterized in that said solvent-polymer separation device comprises:

a gas-liquid separation section or a plurality of gas-liquid separation sections operating in series, preferably at least two, preferentially between two and five, for example three or four, successive gas-liquid separation sections,

at least one system for controlling the pressure in said gas-liquid separation section or in each gas-liquid separation section of the series, so as to adjust the pressure in said gas-liquid separation section or in each gas-liquid separation section of the series to a value lower than the operating pressure at the outlet of the purification means, and when said solvent-polymer separation device comprises a plurality of gas-liquid separation sections, so as to adjust the pressure in the subsequent section to a value lower than that in the preceding section,

said gas-liquid separation section or each gas-liquid separation section of the series comprising a feed system, a liquid withdrawal system and a gas withdrawal system,

wherein the feed system of said gas-liquid separation section or of the first gas-liquid separation section of the series is connected to at least one of the purification means and allows purified polymer solution to be fed to said solvent-polymer separation device,

wherein, when said solvent-polymer separation device comprises a plurality of gas-liquid separation sections, the feed system of the subsequent section is connected to the liquid withdrawal system of the preceding section,

wherein the liquid withdrawal system of said gas-liquid separation section or of the last gas-liquid separation section of the series makes it possible to recover said stream of purified thermoplastic polymers,

wherein the gas withdrawal system of said gas-liquid separation section or of each gas-liquid separation section of the series makes it possible to recover said at least one solvent effluent to be recovered, said at least one solvent effluent comprising dissolution solvent.

10 DESCRIPTION OF THE EMBODIMENTS

In the present description, the expressions “of between ... and ...” and “between ... and ...” are equivalent and mean that the limit values of the interval are included in the described range of values. If such is not the case and if the limit values are not included in the range described, it will be indicated as such in the present description.

15 In the present description, the term “greater than...” is understood as strictly greater than, and is symbolized by the sign “>”, and the term “less than...” is understood as strictly less than, and is symbolized by the sign “<”. When the limit is included, this detail will be indicated by the respective expressions “greater than or equal to...” (and corresponding to the sign “≥”) and “less than or equal to” (corresponding to the sign “≤”).

20 For the purposes of the present invention, the various ranges of parameters for a given step, such as the pressure ranges and the temperature ranges, can be used alone or in combination. For example, in the sense of the present invention, a range of preferred pressure values can be combined with a range of more preferred temperature values.

In the description hereinbelow, particular embodiments of the invention are described. They can be carried out separately or combined together, without limitation of combinations when this is technically achievable.

According to the present invention, the pressures are absolute pressures and are given either in MPa or in MPa absolute (or MPa abs).

30 The terms “upstream” and “downstream” should be understood as a function of the general flow of the fluid(s) or stream(s) under consideration in the process, in particular as a function of the flow of the stream comprising the thermoplastics to be purified.

In the present description, the terms “polymer”, “thermoplastic polymer” and “thermoplastic” may be used interchangeably.

The term "polyolefins" refers to any type of homopolymer and/or copolymer, and mixtures thereof, having olefins as the basic unit. More particularly, polyolefins can be polyethylene homopolymers, designated by the abbreviation PE, of any range (for example high density, also called HDPE, or low density, called LDPE), polypropylene homopolymers, designated
5 by the abbreviation PP, copolymers thereof and/or mixtures thereof.

The term "additives" is a term conventionally used in the field of polymers and in particular in the field of polymer formulations. The additives introduced into the polymer formulations may be, for example, plasticizers, fillers (which are organic or mineral solid compounds used for modifying the physical, thermal, mechanical and/or electrical properties of polymer materials
10 or for reducing the cost price thereof), reinforcing agents, colorants, plasticizers, pigments, hardeners, flame retardants, combustion retardants, stabilizers, antioxidants, UV absorbers, antistatic agents, etc.

The additives correspond to at least some of the impurities of the plastic feedstock to be treated and which the treatment process according to the invention makes it possible to at
15 least partly remove. Other types of impurities eliminated during the process according to the invention may be use-related impurities, for instance metal impurities, papers/cardboard, biomass, polymers other than the targeted polymer(s), etc.

Thus, according to the invention, the impurities which the process according to the invention makes it possible to at least partly remove comprise the additives conventionally used in
20 polymer formulations, and in particular thermoplastic formulations, and also possibly use-related impurities derived from the life cycle of the plastic articles and materials, and/or derived from the waste collection and sorting channel. Said impurities may be impurities of metallic, organic or mineral type; they may be packaging residues, food residues or compostable residues (biomass). These use-related impurities may also comprise glass,
25 wood, cardboard, paper, aluminium, iron, metals, tyres, rubber, silicones, rigid polymers, thermosetting polymers, thermoplastics of a nature different from that of the targeted thermoplastics (in particular from that of the targeted polyolefins), household, chemical or cosmetic products, used oils, water, etc.

According to the invention, a polymer solution is a solution comprising the dissolution solvent
30 and at least the targeted thermoplastic polymers, in particular the targeted polyolefins, which are dissolved, i.e. in particular solvated and dispersed, in said dissolution solvent, the dissolved polymers being initially present in the plastic feedstock. The polymer solution may also comprise impurities which are insoluble (and suspended in the polymer solution) and optionally soluble (and dissolved in the dissolution solvent). Depending on the steps of the
35 process according to the invention which are used, said polymer solution may thus comprise,

besides the dissolved targeted thermoplastics, impurities in the form of insoluble particles which are advantageously suspended in said polymer solution, optionally soluble impurities dissolved in the dissolution solvent, and/or optionally another liquid phase that is immiscible with said polymer solution.

- 5 It is well known that the boiling point of a compound varies with the operating pressure. However, without further indication, in particular without indication of the pressure, the boiling point of the compound under consideration, in particular of the dissolution solvent, is to be understood as the boiling point of said compound, in particular of said dissolution solvent, at atmospheric pressure (in particular equal to 0.1 MPa). Thus, the boiling point characterizing
10 the dissolution solvent is to be understood as the boiling point of said dissolution solvent at atmospheric pressure (in particular equal to 0.1 MPa).

The critical temperature and critical pressure of a solvent, in particular of the dissolution solvent, are specific to said solvent and depend on the nature of the solvent under consideration. For a pure substance, the critical temperature and the critical pressure of a
15 pure substance are, respectively, the temperature and the pressure of the critical point of said pure substance. As is well known to those skilled in the art, at and above the critical point, the pure substance under consideration is in supercritical form or in the supercritical state; it may then be referred to as a supercritical fluid.

The invention thus relates to a process for treating a plastic feedstock, comprising
20 thermoplastics, more particularly polyolefins, said process comprising, and preferably consisting of:

a) a step of dissolving the plastic feedstock in a dissolution solvent, preferably comprising at least one hydrocarbon-based compound, preferably an aliphatic and preferably paraffinic compound, advantageously having a boiling point of between -50°C and 250°C, preferably
25 between -15°C and 200°C, preferentially between 15 and 160°C and preferably between 20°C and 120°C, preferably in a weight ratio between the dissolution solvent and the plastic feedstock of between 0.2 and 100.0, preferably between 0.3 and 20.0, preferably between 1.0 and 10.0, even more preferentially between 3.0 and 7.0, to obtain at least one crude polymer solution,

30 step a) advantageously being performed at a dissolution temperature of between 100°C and 300°C, preferably between 150°C and 250°C, and at a dissolution pressure of between 0.1 and 100.0 MPa absolute, preferably between 1.0 and 25.0 MPa absolute, preferentially between 1.5 and 18.0 MPa absolute and very preferably between 2.0 and 15.0 MPa absolute;

35 b) a step of purifying the crude polymer solution, comprising:

b1) a sub-step of separating out the insoluble matter to obtain at least one clarified polymer solution; and/or

b2) a washing sub-step, by contact with a dense solution, to obtain a washed polymer solution; and/or

5 b3) a sub-step of extraction of the impurities with an extraction solvent, to obtain at least one extracted polymer solution; and/or

b4) a sub-step of adsorption of the impurities by contact with an adsorbent, to obtain at least one refined polymer solution;

10 the purification step making it possible to obtain a purified polymer solution which advantageously corresponds to a clarified or washed or extracted or refined polymer solution; and then

c) a step of solvent-polymer separation of the purified polymer solution, to obtain at least one stream of purified thermoplastic polymers, more particularly at least one stream of purified polyolefins, and at least one solvent stream,

15 wherein said solvent-polymer separation step c) implements of a gas-liquid separation section or a plurality of gas-liquid separation sections operating in series, the solvent-polymer separation step c) preferably making use of at least two successive gas-liquid separation sections,

20 wherein said gas-liquid separation section or each of the gas-liquid separation sections is operated at an inlet temperature of between 100°C and 300°C, preferably between 110°C and 275°C, preferably between 150°C and 250°C, and at a pressure lower than that at the outlet of step b), preferably at a pressure of less than 100.0 MPa absolute, preferably less than 25.0 MPa absolute, preferentially less than 18.0 MPa absolute, preferably less than 15.0 MPa absolute,

25 wherein, when step c) implements a plurality of gas-liquid separation sections, the pressure of the subsequent section is lower than that of the preceding section,

preferably the pressure in the gas-liquid separation section or each of the gas-liquid separation sections being greater than or equal to 0.000005 MPa absolute, in particular greater than or equal to 0.00001 MPa absolute, in particular greater than or equal to 0.0001 MPa absolute, more particularly greater than or equal to 0.0005 MPa absolute, and particularly greater than or equal to 0.0008 MPa,

wherein said purified polymer solution, obtained from the purification step b), feeds into said gas-liquid separation section or into the first gas-liquid separation section of the series,

said gas-liquid separation section or each of the gas-liquid separation sections producing a gaseous effluent, which corresponds to said at least one solvent stream and which advantageously comprises at least dissolution solvent, and a liquid effluent which advantageously comprises the targeted thermoplastics,

5 wherein, when step c) implements a plurality of gas-liquid separation sections, the liquid effluent from the preceding section feeds into the subsequent section,

the liquid effluent from said gas-liquid separation section or from the last gas-liquid separation section in the series constituting said stream of purified thermoplastic polymers,

10 the or each gaseous effluent produced may be, totally or partly, purged and/or purified and/or fractionated and/or recycled to step a) and/or optionally to step b),

optionally step c) comprising the introduction of at least one additive, in particular an antioxidant,

optionally step c) also implementing an intermediate liquid-liquid or supercritical-liquid separation section located upstream of the gas-liquid separation section or of the series of
15 gas-liquid separation sections.

The feedstock

The feedstock of the process according to the invention, known as the plastic feedstock, comprises plastics which themselves more particularly comprise thermoplastic polymers, such as polyolefins. Preferably, the plastic feedstock comprises between 50% and 100% by
20 weight and preferably between 70% and 100% by weight of plastics relative to the total weight of the plastic feedstock.

The plastics included in the feedstock of the process according to the invention are generally production scrap and/or "post-consumer" waste plastic articles, including household plastic waste, plastic waste from the construction industry, plastic waste from motor vehicles or from
25 any type of transport or waste electrical and electronic equipment. Preferably, the plastic waste is derived from collection and sorting channels. Plastics or plastics materials are generally compositions (or formulations) comprising polymers which are mixed with additives so as to give the materials specific properties, with a view to constituting, after shaping, various articles (for example injection-moulded parts, tubes, films, fibres, fabrics, mastics,
30 coatings, etc.). The additives used in plastics may be organic compounds or inorganic compounds. They are, for example, fillers, colorants, pigments, plasticizers, property modifiers, flame retardants, etc.

The feedstock of the process according to the invention (i.e. the plastic feedstock) in particular comprises thermoplastic polymers, preferably at least 50% by weight, preferentially

at least 70% by weight, preferably at least 80% by weight and very preferably at least 90% by weight of thermoplastics, relative to the total weight of the plastic feedstock, 100% advantageously being the maximum upper limit. The thermoplastics targeted by the process according to the invention and included in the plastic feedstock may be alkene polymers (or
 5 olefins), diene polymers, vinyl polymers and/or styrene polymers. Preferably, the thermoplastics targeted by the process according to the invention and included in the plastic feedstock are polyolefins, such as polyethylene (PE), polypropylene (PP) and/or copolymers of ethylene and propylene or mixtures thereof. Preferably, the plastic feedstock comprises at least 80% by weight, preferably at least 85% by weight, preferably at least 90% by weight, of
 10 polyolefins relative to the total weight of the plastic feedstock, 100% advantageously being the maximum upper limit. The process according to the invention is thus very particularly directed towards purifying and recovering the polyolefins contained in a plastic feedstock, in particular derived from plastic waste, so that they can be reused in various applications.

According to a particular embodiment, the plastic feedstock comprises a mixture of
 15 polypropylene (PP) and polyethylene (PE), in particular at least 80% by weight, preferably at least 85% by weight, preferably at least 90% by weight, of a mixture of polypropylene (PP) and polyethylene (PE), relative to the total weight of the plastic feedstock. The polyethylene may more particularly be high-density polyethylene (HDPE). In this particular embodiment, said mixture comprises for example between 5% and 95% by weight of PP and between 5%
 20 and 95% by weight of PE, in particular HDPE, or between 50% and 95% by weight of PP and between 5% and 50% by weight of PE, in particular HDPE.

The plastic feedstock may comprise blends of polymers, in particular thermoplastics other than the targeted thermoplastics, and in particular other than the targeted polyolefins, additives advantageously used for formulating the plastic material and possibly use-related
 25 impurities originating from the life cycle of the plastic materials and articles and/or originating from the waste collection and sorting circuit, these compounds being collectively considered as impurities. The feedstock of the process according to the invention generally comprises less than 50% by weight of impurities, preferably less than 20% by weight of impurities, preferably less than 10% by weight of impurities. The plastic feedstock may comprise, for
 30 example, at least 1% by weight of impurities, or even at least 5% by weight of impurities.

The plastic feedstock may advantageously be pretreated upstream of the process according to the invention so as to at least remove all or some of the "coarse" impurities, i.e. impurities in the form of particles greater than or equal to 10 mm, preferably greater than or equal to 5 mm, or even greater than or equal to 1 mm in size, for example impurities such as wood,
 35 paper, biomass, iron, aluminium, glass, etc., and so as to form it, generally into the form of divided solids so as to facilitate the treatment in the process. This pretreatment may

comprise a milling step, a step of washing at atmospheric pressure and/or a drying step. This pretreatment may be performed at a different site, for example in a waste collection and sorting centre, or at the same site where the treatment process according to the invention is performed. Preferably, this pretreatment makes it possible to reduce the content of impurities to less than 20% by weight, preferably less than 15% by weight, preferably less than 10% by weight, the percentages being given relative to the weight of the plastic feedstock treated by means of the process according to the invention. At the end of the pretreatment, the feedstock is generally stored in the form of divided solids, for example in the form of ground material, flakes or powder or granules, so as to facilitate the handling and transportation into the process.

Dissolution step a)

According to the invention, the process comprises a dissolution step a) in which the plastic feedstock is placed in contact with a dissolution solvent, to obtain at least one, preferably one, crude polymer solution. Specifically, this step advantageously enables the dissolution of at least some and preferably of all of the targeted thermoplastics, preferably of the targeted polyolefins, present in the plastic feedstock.

The term "dissolution" should be understood as meaning any phenomenon leading to the production of at least one solution of thermoplastic polymers, i.e. a liquid (or fluid) comprising the targeted thermoplastic polymers dissolved in the dissolution solvent. A person skilled in the art is fully aware of the phenomena involved in the dissolution of polymers, these phenomena involving at least mixing, solvating, dispersion, homogenization and disentangling of the thermoplastic polymer chains.

In the course of and at the end of the dissolution step a), the pressure and temperature conditions make it possible to maintain the dissolution solvent, at least partly and preferably totally, in liquid form or optionally in supercritical form, whereas the soluble fraction of the plastic feedstock, in particular the targeted thermoplastic polymers, for example the targeted polyolefins, and possibly (or even generally) at least a portion of the impurities, is advantageously at least partly and preferably totally dissolved in the dissolution solvent. In other words, the temperature and pressure conditions in step a) avoid or at least limit the possibility of the dissolution solvent being in gaseous form, which enables the dissolution of the targeted thermoplastics to be optimized.

The dissolution solvent is an organic solvent or a mixture of organic solvents.

Advantageously, the dissolution solvent comprises, and preferably consists of, at least one preferably aliphatic and in particular paraffinic (i.e. saturated), preferably linear, branched or cyclic, preferentially non-aromatic hydrocarbon-based compound. Preferably, the dissolution

solvent comprises at least 80% by weight, preferentially at least 95% by weight, preferably at least 98% by weight of at least one preferably aliphatic and in particular paraffinic, preferably linear, branched or cyclic, preferentially non-aromatic hydrocarbon-based compound, the percentages being expressed relative to the total weight of the dissolution solvent (100% being the maximum). Preferably, the dissolution solvent comprises, and preferably consists of, at least one preferably aliphatic and in particular paraffinic hydrocarbon-based compound, having a boiling point (at atmospheric pressure, in particular at 0.1 MPa) of between -50 and 250°C, preferably between -15 and 200°C, preferentially between 15 and 160°C and preferably between 50 and 120°C. Preferably, said at least one preferably aliphatic and in particular paraffinic, preferentially linear, branched or cyclic, preferentially non-aromatic hydrocarbon-based compound, contains between 3 and 12 carbon atoms, preferably between 4 and 10 carbon atoms, preferentially between 5 and 8 carbon atoms, and very preferably contains 6, 7 or 8 carbon atoms. For example, said at least one preferably aliphatic and in particular paraffinic, preferably linear, branched or cyclic, preferentially non-aromatic, hydrocarbon-based compound may be chosen from isomers of butane, pentane, hexane, heptane, octane, nonane, decane and mixtures thereof, preferably from isomers of hexane, heptane, octane and mixtures thereof. Thus, the dissolution solvent may comprise at least 80% by weight, preferentially at least 95% by weight, preferably at least 98% by weight, of an isomer or mixture of isomers of butane, pentane, hexane or heptane, octane, nonane and/or decane, preferably an isomer or mixture of isomers of hexane, heptane and/or octane, the percentages being expressed relative to the total weight of the dissolution solvent (100% being the maximum).

Preferably, the dissolution step a) is fed with the plastic feedstock and said dissolution solvent in a weight ratio between the dissolution solvent and the plastic feedstock of between 0.2 and 100.0, preferably between 0.3 and 20.0, preferably between 1.0 and 10.0, even more preferentially between 3.0 and 7.0.

Advantageously, the dissolution solvent which feeds the dissolution step a) is in liquid or possibly supercritical form. Advantageously, it can be preheated, preferably to a temperature between 100 and 300°C, preferentially between 150 and 250°C, prior to its introduction into step a), in particular prior to its introduction into the contacting section and optionally into the dissolution section, so as to facilitate the heating of the plastic feedstock and/or to avoid a temperature drop of the material stream during the contacting and dissolution operations in step a).

Advantageously, the dissolution solvent comprises, and preferably consists of, fresh solvent (or a supply of fresh solvent) and/or a stream of recycled solvent obtained from a subsequent

step of the process, preferably at least partly obtained from the solvent-polymer separation step c).

Very advantageously, the dissolution step is performed at a temperature, known as the dissolution temperature, of between 100°C and 300°C, preferably between 150°C and 250°C, and preferably a pressure, known as the dissolution pressure, of between 1.0 and 100.0 MPa absolute, preferably between 1.0 and 25.0 MPa absolute, preferentially between 1.5 and 18.0 MPa absolute and very preferably between 2.0 and 15.0 MPa absolute. The temperature and pressure can change during the dissolution step from atmospheric conditions or the conditions of introduction of the plastic feedstock and/or dissolution solvent into the process, to reach the dissolution conditions, i.e. the dissolution temperature, in particular between 100°C and 300°C, preferably between 150°C and 250°C, and the dissolution pressure, in particular between 0.1 and 100.0 MPa, preferably between 1.0 and 25.0 MPa absolute, preferentially between 1.5 and 18.0 MPa absolute and very preferably between 2.0 and 15.0 MPa absolute. Very advantageously, at the end of the dissolution step, the crude polymer solution is at the dissolution temperature and the dissolution pressure.

Limiting the temperature in the dissolution step a) to a temperature below or equal to 300°C, preferably below or equal to 250°C, makes it possible to avoid or limit the thermal degradation of the targeted thermoplastics, in particular of the targeted polyolefins, but also to limit the energy requirement of the process, thus helping to limit the operating costs of the process. Advantageously, the dissolution temperature is above or equal to the melting point of the targeted thermoplastics, in particular of the targeted polyolefins, and very advantageously below the evaporation temperature at the dissolution pressure of the dissolution solvent, so as to promote their dissolution and very advantageously reduce the residence time required to effectively dissolve said thermoplastics in the dissolution solvent.

Very preferably, the temperature in the dissolution step a) is below or equal to the critical temperature of the dissolution solvent, so as to avoid the formation of a supercritical phase during the dissolution step a) which is liable to disrupt the dissolution.

At the same time, the dissolution pressure in the dissolution step a) is higher than the saturation vapour pressure of the dissolution solvent at the dissolution temperature, so that the dissolution solvent is at least partly, and preferably entirely, in liquid or possibly supercritical form at the dissolution temperature, and thus to avoid the dissolution solvent being partly in gaseous form. Under these operating conditions, in particular these temperature and pressure conditions, the dissolution of the targeted thermoplastics, in particular of the targeted polyolefins, is optimized, especially in terms of quality and operation time.

Very advantageously, the dissolution temperature and pressure conditions reached in the dissolution step a) are adjusted so that the mixture (dissolution solvent + targeted thermoplastics) is single-phase at the end of step a), said mixture possibly comprising insoluble impurities suspended in said mixture.

- 5 Advantageously, said dissolution step a) is performed for a residence time preferably of between 1 and 600 minutes, preferably between 2 and 300 minutes, preferably between 2 and 180 minutes. The residence time is understood as being the residence time at the dissolution temperature and at the dissolution pressure, i.e. the time during which the plastic feedstock and the dissolution solvent are at the dissolution temperature and at the
10 dissolution pressure, in step a).

The dissolution step a) is at least fed with the plastic feedstock, in particular in the form of one or more streams of plastic feedstock, and with the dissolution solvent, in particular in the form of one or more streams of dissolution solvent, advantageously by means of one or more transporting devices. The stream(s) of plastic feedstock may be distinct from the stream(s) of
15 dissolution solvent. Some or all of the plastic feedstock may also feed into step a) as a mixture with some or all of the dissolution solvent, the remainder of the solvent and/or of the feedstock, where appropriate, possibly feeding into step a) separately.

During the contacting of the plastic feedstock with the dissolution solvent, the dissolution solvent is advantageously at least partly, and preferably totally, in liquid or possibly
20 supercritical form, whereas the plastic feedstock, which comprises the targeted thermoplastics, may be in solid or liquid form optionally comprising solid particles in suspension. The plastic feedstock may also optionally be injected into the dissolution equipment, as a mixture with the dissolution solvent, in the form of a suspension in the dissolution solvent, it being possible for the preparation and injection of the suspension to be
25 continuous or batchwise.

In order to enable the dissolution solvent and the plastic feedstock to be placed in contact with each other and, above all, to enable the targeted thermoplastics to be dissolved efficiently and homogeneously in the dissolution solvent, the dissolution step a) may advantageously implement various types of equipment such as mixing, transporting and
30 heating devices, for instance a reactor, a pump, a transport circuit, a stirring system, an oven, an exchanger, a mixer, etc. In particular, step a) advantageously implements at least one item of dissolution equipment, and optionally at least one feedstock preparation device, a mixing device and/or a transporting device. The items of equipment and/or devices used in step a) may be, for example, one or more static or dynamic mixers, an extruder, a pump, a
35 reactor, a co-current or counter-current column and/or transporting devices, advantageously

connected to each other. Devices for transportation in particular of fluids, such as gases, liquids or solids, are well known to those skilled in the art. In a non-limiting manner, the transporting devices may comprise at least one of the following devices: a compressor, a pump, an extruder, a vibrating tube, an endless screw or a valve. The items of equipment and/or devices used in step a) may also comprise or be combined with heating systems (for example oven, exchanger, trace heating, etc.) to achieve the conditions required for dissolution.

Preferably, the dissolution step a) implements at least one means for at least partially melting the plastic feedstock, preferably an extruder, optionally at least one means for mixing at least part of the dissolution solvent and the advantageously at least partially melted plastic feedstock, such as one mixer or a series of two to ten mixers (preferably one to ten static mixers), and dissolution equipment, for example at least one continuous stirred tank reactor (CSTR), equipped with at least one mechanical stirring system. In this case, the plastic feedstock feeds the melting means, in particular the extruder, so that, at the outlet of said means, at least some and preferably all of the targeted thermoplastics included in the plastic feedstock are in the melt state. The plastic feedstock may then be injected into the dissolution equipment, for example a reactor of the continuous stirred reactor (or CSTR) type, or optionally into a system comprising a mixer or series of mixers advantageously followed by a reactor of the continuous stirred reactor (or CSTR) type, for example. The plastic feedstock, at least partly in the melt state, may also be pumped by means of a pump dedicated to viscous fluids, often known as a melt pump or a gear pump. The plastic feedstock at least partly in the melt state may, at the outlet of said melting means, also be filtered by means of a filtration device, optionally in addition to the melt pump, for the purpose of removing the coarsest particles; generally, the mesh size of this filter is between 10 μm (micrometres) and 1 mm (millimetre), preferably between 20 and 200 μm . At the same time, the dissolution solvent feeds directly into the dissolution equipment, said melting means, in particular the extruder, and/or the mixer or the series of mixers.

Preferably, step a) implements, prior to at least one CSTR-type reactor, an extruder followed by at least one static mixer into which at least a fraction of the dissolution solvent is injected, so as to promote shearing and intimate mixing between the dissolution solvent and the plastic feedstock, thus contributing towards the dissolution of the targeted thermoplastics.

Very advantageously, the crude polymer solution obtained from the dissolution step a) comprises at least the dissolution solvent and the targeted thermoplastics, in particular the targeted polyolefins, dissolved in the dissolution solvent. In general, the crude polymer solution also comprises soluble impurities that are also dissolved in the dissolution solvent and/or insoluble impurities in suspension. The crude polymer solution obtained from the

dissolution step a) may optionally also comprise polymers, for example in the melt state, which are optionally dissolved.

Step b) of purification of the polymer solution

5 The purification process according to the invention comprises a step of purifying the crude polymer solution obtained from step a). This purification step b) comprises at least one of the sub-steps b1), b2), b3) and b4) described below:

b1) a sub-step of separating out the insoluble matter,

b2) a sub-step of washing, by contact with a dense solution,

b3) a sub-step of extraction, by contact with an extraction solvent,

10 b4) a sub-step of adsorption of the impurities by contact with an adsorbent.

The various sub-steps b1), b2), b3) and b4) may be performed continuously, in batch mode or in fed-batch mode.

15 Preferably, the purification step b) comprises at least one sub-step b1) of separating out the insoluble matter. Preferably, the purification step b) comprises several (i.e. at least two) sub-steps chosen from sub-steps b1), b2), b3) and b4), in series relative to each other, and preferably at least one sub-step b1) of separating out the insoluble matter and, for example, one adsorption sub-step b4), very advantageously in the order b1) then b4). The combination of at least two sub-steps chosen from b1), b2), b3) and b4) advantageously allows optimum purification of the polymer solution, which consequently makes it possible to obtain a stream
20 of purified thermoplastics having very low impurity contents, preferably less than or equal to 5% by weight, preferentially less than or equal to 1.0% by weight, preferably less than or equal to 0.5% by weight, relative to the total weight of the stream of purified thermoplastics.

The polymer solution obtained from step b) is a purified polymer solution which comprises the targeted thermoplastics, in particular the targeted polyolefins, dissolved in the dissolution
25 solvent. This purified polymer solution may correspond to a clarified polymer solution obtained from a sub-step b1) of separating out the insoluble matter, a washed polymer solution obtained from a washing sub-step b2), an extracted polymer solution obtained from an extraction sub-step b3) or a refined polymer solution obtained from a sub-step b4) of adsorbing the impurities.

30 Preferably, the temperature and pressure in step b) are adjusted so as to obtain a polymer solution, i.e. the purified polymer solution, in liquid form at the end of step b).

Sub-step b1) of separating out the insoluble matter

The purification process may comprise a sub-step b1) of separating out the insoluble matter, in particular by solid-liquid separation, so as advantageously to obtain at least one clarified polymer solution (i.e. free of at least some, preferably all, of the insoluble impurities of the crude polymer solution), and preferably at least one insoluble fraction. Said at least one insoluble fraction advantageously comprises at least some, preferably all, of the insoluble impurities, in particular in suspension in the crude polymer solution obtained from step a), possibly dissolution solvent and possibly soluble impurities.

Sub-step b1) of separating out the insoluble matter thus makes it possible to remove at least a portion, and preferably all, of the insoluble impurities present in suspension in the crude polymer solution obtained from step a). The insoluble impurities removed during the sub-step b1) of separating out the insoluble matter are, for example, pigments, mineral compounds, packaging residues (glass, wood, cardboard, paper, aluminium) and insoluble polymers. When it is performed, this separation sub-step b1) advantageously makes it possible, besides removing at least a portion of the insoluble impurities, to limit the operating problems, in particular such as clogging and/or erosion, of the process steps downstream of such a sub-step b1), while at the same time contributing towards the purification of the plastic feedstock.

Sub-step b1) of separating out the insoluble matter is advantageously performed at a temperature of between 100°C and 300°C, preferably between 150°C and 250°C, preferentially between 160°C and 225°C, very preferentially between 165°C and 210°C and preferably between 170°C and 195°C, and a pressure of between 0.1 and 100.0 MPa absolute, preferably between 1.0 and 25.0 MPa absolute, preferentially between 1.0 and 18.0 MPa absolute and very preferably between 1.5 and 15.0 MPa absolute. Very advantageously, sub-step b1) of separating out the insoluble matter is performed under the temperature and pressure conditions at the outlet of dissolution step a), i.e. at the dissolution temperature and dissolution pressure as defined above, optionally with a lowered pressure, preferably from 0.01 to 10.0 MPa, preferably from 0.1 to 5.0 MPa due to the pressure drops experienced between step a) and sub-step b1).

When integrated into the process, sub-step b1) of separating out the insoluble matter is preferably fed with the crude polymer solution from step a) or any other polymer solution from sub-step b2), b3) or b4) optionally located upstream of sub-step b1). According to a preferred embodiment, sub-step b1) is fed with the crude polymer solution from step a). According to another embodiment, sub-step b1) may be fed with a washed polymer solution from a washing sub-step b2), located upstream of sub-step b1).

Advantageously, sub-step b1) implements any solid-liquid separation step known to those skilled in the art for separating out insoluble matter, whether solid (such as additives of the mineral filler or pigment type) or liquid (for example polymers in molten form and of a different nature from that of the targeted thermoplastics), for example a step of separation by
 5 decantation, filtration, centrifugation, electrostatic separation, etc.

Preferably, sub-step b1) comprises at least one, preferably between one and five, preferentially between in particular and five, solid-liquid separation step(s) (or solid-liquid-liquid separation step(s), notably in the case where the effluent obtained from the dissolution step comprises, in addition to the polymer solution and the solid impurities, impurities and/or
 10 polymers in liquid form which are insoluble or sparingly soluble, and of a different nature from that of the targeted thermoplastics). When it is performed, sub-step b1) preferably comprises several, i.e. between two and five, solid-liquid separation (or solid-liquid-liquid separation) steps in series and/or in parallel. The presence of at least two solid-liquid separation steps in series allows improved removal of the insoluble matter, while the presence of several solid-
 15 liquid separation steps in parallel allows management of the equipment maintenance and/or the unclogging operations. According to a preferred embodiment, sub-step b1) of separating out the insoluble matter implements a step of solid-liquid separation by decantation and/or at least one, preferably between one and four, steps of solid-liquid separation by filtration.

Said at least one solid-liquid separation step preferably implements at least one item of solid-
 20 liquid separation equipment, for example a separating vessel, a decanter, a centrifugal decanter, a centrifuge, a filter, a sand filter, a cross-flow filter in particular implementing a membrane and/or a depth filter, an eddy current separator, an electrostatic separator, a triboelectric separator, and preferably a decanter, a filter, a sand filter and/or an electrostatic separator. Advantageously, a self-cleaning filter may be used, the cleaning or unclogging
 25 allowing the removal of the insoluble matter being performed using a solvent stream. During sub-step b1), filtration adjuvants (for example diatomaceous earth or sand) may optionally be added prior to a decantation step and/or a filtration-based separation step.

Depending on the nature of the feedstock, the polymer solution which feeds sub-step b1), preferably the crude polymer solution, may optionally also comprise a second liquid phase,
 30 for example consisting of molten polymers, these polymers being of a different nature from that of the targeted thermoplastics. According to another particular embodiment, sub-step b1) advantageously implements a solid-liquid-liquid separation section, using equipment allowing the separation of two liquid phases and one solid phase, preferably by means of at least one two-phase or three-phase separator.

Said at least one insoluble fraction is preferably removed or treated so as to separate out and recover compounds of interest, for example polymers, in particular thermoplastics, and/or the dissolution solvent which it may contain. The removal or treatment of said at least one insoluble fraction may be facilitated by equipment allowing the transport and/or
 5 separation of any polymer and/or solvent present in the insoluble fraction, for example a conveyor, a vibrating tube, an endless screw, an extruder or a stripper. Sub-step b1) may implement transporting and/or separating equipment to remove and/or treat said at least one insoluble fraction. Advantageously, sub-step b1) comprises the separation and recovery of at least part of the solvent, in particular of the dissolution solvent, contained in said at least one
 10 insoluble fraction, said at least part of the solvent, in particular of the dissolution solvent, being able to be recycled into the process, in particular into step a).

Certain insoluble impurities, including certain pigments and mineral fillers, conventionally added during the formulation of polymers, may be in the form of particles less than 1 μm in size. This is the case, for example, for titanium dioxide, calcium carbonate and carbon black.
 15 According to a particular embodiment of sub-step b1), said sub-step b1) of separating out the insoluble matter advantageously uses an electrostatic separator, which makes it possible to efficiently remove, at least in part, the insoluble particles less than 1 μm in size. According to another particular embodiment of sub-step b1), sub-step b1) of separating out the insoluble matter uses a sand filter, to remove the particles of various sizes and in particular the
 20 particles less than 1 μm in size. According to yet another particular embodiment, sub-step b1) of separating out the insoluble matter uses a cross-flow filter in particular implementing a membrane and/or a depth filter, optionally in the presence of filtration adjuvants, for instance diatomaceous earth.

Washing sub-step b2)

25 The treatment process may optionally comprise a sub-step b2) of washing with a dense solution, to advantageously obtain a washed polymer solution and preferably at least one washing effluent. The washed polymer solution obtained from sub-step b2) advantageously comprises the targeted thermoplastics, dissolved in the dissolution solvent. Optionally, the washed polymer solution may also comprise residual impurities which are in particular
 30 soluble in the dissolution solvent and/or possibly traces of the washing solvent when sub-step b2) is performed.

The washing sub-step b2) may be incorporated upstream or downstream, preferably downstream, of a sub-step b1) of separating out the insoluble matter, when these two sub-steps are incorporated into the treatment process according to the invention.

When it is incorporated into the process, the washing sub-step b2) is fed with a dense solution and with the polymer solution obtained from the step or sub-step immediately upstream of b2), in particular with the crude polymer solution obtained from step a) or the clarified polymer solution obtained from a sub-step b1). The polymer solution which feeds the washing sub-step b2), in particular the crude or optionally clarified polymer solution, may comprise insoluble impurities in suspension and/or dissolved impurities. These suspended or dissolved impurities may be partly or totally removed during the washing sub-step b2) by dissolution or precipitation and/or by entrainment in the dense solution. Thus, when it is performed, this sub-step b2) contributes towards the treatment of the plastic feedstock and more particularly towards the purification of the polymer solution.

The washing sub-step b2) advantageously involves contacting the polymer solution which feeds sub-step b2), in particular the crude or clarified polymer solution, with a dense solution. Advantageously, the dense solution has a higher density than the polymer solution (i.e. the mixture comprising at least the targeted thermoplastics and the dissolution solvent in which the targeted thermoplastics are dissolved), in particular greater than or equal to 0.85, preferably greater than or equal to 0.9, preferentially greater than or equal to 1.0. The dense solution may be an aqueous solution, which preferably comprises at least 50% by weight of water, preferably at least 75% by weight of water, very preferably at least 90% by weight of water. The pH of the aqueous solution may be adjusted using an acid or a base so as to promote the dissolution of certain impurities. The dense solution may also optionally be a solution comprising, preferably consisting of, an organic solvent with a density advantageously greater than or equal to 0.85, preferably greater than or equal to 0.9, preferentially greater than or equal to 1.0, and in which the polymers of the plastic feedstock remain insoluble under the temperature and pressure conditions of sub-step b2). Thus, the dense solution may comprise, in particular consist of, an organic solvent chosen, for example, from sulfolane or N-methylpyrrolidone (NMP), optionally as a mixture with water. Very preferably, the dense solution is an aqueous solution which preferably comprises at least 50% by weight of water, preferably at least 75% by weight of water, very preferably at least 90% by weight of water.

The washing sub-step b2) is advantageously performed at a temperature of between 100°C and 300°C, preferably between 150°C and 250°C, and very advantageously at a pressure of between 0.1 and 100.0 MPa absolute, preferably between 1.0 and 25.0 MPa absolute, preferentially between 1.0 and 18.0 MPa absolute and very preferably between 1.5 and 15.0 MPa absolute. Very advantageously, the washing sub-step b2) is performed at the dissolution temperature and the dissolution pressure, optionally with a lowered pressure,

preferably from 0.01 to 10.0 MPa, preferably from 0.1 to 5.0 MPa due to the pressure drops experienced between step a) and sub-step b2).

In the washing sub-step b2), when it is incorporated into the process, the mass ratio between the mass flow rate of the dense solution relative to the mass flow rate of the polymer solution which feeds sub-step b2), in particular of the crude or clarified polymer solution, is advantageously between 0.05 and 20.0, preferably between 0.1 and 10.0 and preferably between 0.5 and 3.0. The polymer solution, in particular the crude or clarified polymer solution, and the dense solution may be brought into contact at several points in the equipment used, i.e. via several injections of the polymer solution and/or of the dense solution at various points along the equipment; it is then the sum of the streams injected that is taken into account in the calculation of the mass ratio.

Sub-step b2) may implement one or more items of washing equipment enabling the polymer solution to be brought into contact with the dense solution and/or one or more items of separation equipment making it possible to recover at least one washing effluent and one washed polymer solution. This equipment is well known to those skilled in the art: it is, for example, stirred reactors, static mixers, decanting mixers, two-phase or three-phase separating vessels, co-current or counter-current washing columns, plate columns, stirred columns, packed columns, pulsed columns, etc., each type of equipment possibly comprising one or more items of equipment used alone or in combination with equipment of another type.

According to a preferred embodiment, the washing sub-step b2) is performed in a counter-current washing column. In this preferred embodiment, the dense solution is advantageously injected into the upper part of the column, preferably into the upper half, preferably the upper third, of the column (the upper part of the column meaning the part closest to the column head), on the one hand, and the polymer solution, in particular the crude or clarified solution, is injected into the lower part of the column, preferably into the lower half, preferably the lower third, of the column (the lower part of the column meaning the part closest to the bottom of the column), on the other hand. According to this embodiment, it is possible to recover at least one washed polymer solution, preferably at the top of the column, and a washing effluent, preferably at the bottom of the column. According to a very particular embodiment, the streams at the washing column inlet and/or outlet may be divided and injected at several injection points along the column and/or withdrawn at several withdrawal points along the column.

According to another embodiment, the washing sub-step b2) is performed in a mixer-decanter comprising a stirred mixing zone, to place the dense solution and the polymer

solution, in particular the crude or clarified polymer solution, in contact, and a decantation zone, making it possible to recover a washed polymer solution and a washing effluent.

At the end of the washing sub-step b2), the washing effluent obtained advantageously comprises impurities dissolved in the dense solution and/or insoluble impurities entrained in the washing effluent. The washing effluent may be retreated in a washing treatment section, on the one hand to at least partly separate out the dissolved and/or entrained impurities and optionally to purify the washing effluent, to obtain a purified dense solution, and on the other hand to recycle at least a portion of the purified dense solution. This optional washing treatment section may implement one or more items of equipment that are well known for solid-liquid separation, for example a separating vessel, a decanter, a centrifugal decanter, a centrifuge or a filter. The washing effluent may also be sent outside the process, for example to a waste water treatment plant when the dense solution is an aqueous solution.

Extraction sub-step b3)

The process according to the invention may comprise a sub-step b3) of extraction advantageously by placing the polymer solution which feeds sub-step b3) in contact with an extraction solvent, to obtain at least one extracted polymer solution and preferably a spent solvent. The extracted polymer solution obtained from sub-step b3) advantageously comprises the targeted thermoplastic polymers, dissolved in the dissolution solvent. The used solvent is advantageously charged with impurities. Optionally, the extracted polymer solution may also comprise residual impurities which are in particular soluble in the dissolution solvent and/or traces of the washing solvent and/or of the extraction solvent if sub-step(s) b2) and/or b3) is (are) performed.

When it is integrated into the treatment process according to the invention, the extraction sub-step b3) is very advantageously located downstream of a sub-step b1) for separating out the insoluble matter, and optionally upstream or downstream of a washing sub-step b2) and/or an adsorption sub-step b4) when the latter are also integrated into the process.

The extraction sub-step b3) is advantageously fed with an extraction solvent and with the polymer solution obtained from the step or sub-step directly upstream of b3), in particular with the crude polymer solution obtained from step a), the clarified polymer solution obtained from sub-step b1), the washed polymer solution obtained from sub-step b2) or the refined polymer solution obtained from a sub-step b4). The polymer solution fed into sub-step b3), in particular the crude, clarified, washed or refined polymer solution, may comprise impurities, in particular dissolved impurities, which may be partly or totally removed during the extraction sub-step b3) by placing in contact with an extraction solvent.

When it is incorporated into the process according to the invention, the extraction sub-step b3) advantageously involves at least one extraction section, preferably between one and five extraction sections, very preferably one extraction section.

Advantageously, the mass ratio between the mass flow rate of the extraction solvent and the mass flow rate of the polymer solution which feeds step b3) is between 0.05 and 20.0, preferably between 0.1 and 10.0 and preferably between 0.2 and 5.0. The placing in contact between the polymer solution which feeds sub-step b3) and the extraction solvent may be performed at several points in the extraction section, i.e. via several injections of the polymer solution and/or of the extraction solvent at different points along the extraction section; it is then the sum of the streams injected that is taken into account in the calculation of the mass ratio.

Preferably, the extraction solvent used in the extraction sub-step b3) comprises an organic solvent or a mixture of organic solvents. Preferably, the extraction solvent comprises, and preferably consists of, at least one preferably aliphatic and in particular paraffinic (i.e. saturated), preferably linear, branched or cyclic, preferentially non-aromatic hydrocarbon-based compound. Preferably, the extraction solvent comprises at least 80% by weight, preferentially at least 95% by weight, preferably 98% by weight of at least one preferably aliphatic and in particular paraffinic, preferably linear, branched or cyclic, preferentially non-aromatic hydrocarbon-based compound, the percentages being expressed relative to the total weight of the dissolution solvent (100% being the maximum). Preferably, the extraction solvent comprises, and preferably consists of, at least one preferably aliphatic and in particular paraffinic hydrocarbon-based compound with a boiling point of between -50 and 250°C, preferably between -15 and 200°C, preferentially between 15 and 160°C and preferably between 50 and 120°C (at atmospheric pressure, in particular at 0.1 MPa). Preferably, said at least one preferably aliphatic and in particular paraffinic, preferably linear, branched or cyclic, preferentially non-aromatic hydrocarbon-based compound, contains between 3 and 12 carbon atoms, preferably between 4 and 10 carbon atoms, preferentially between 5 and 8 carbon atoms, and very preferably contains 6, 7 or 8 carbon atoms. For example, said at least one preferably aliphatic and in particular paraffinic, preferably linear, branched or cyclic, preferentially non-aromatic, hydrocarbon-based compound may be chosen from isomers of butane, pentane, hexane, heptane, octane, nonane, decane and mixtures thereof, preferably from isomers of hexane, heptane, octane and mixtures thereof. Thus, the extraction solvent may comprise at least 80% by weight, preferentially at least 95% by weight, preferably at least 98% by weight, of an isomer or mixture of isomers of butane, pentane, hexane or heptane, octane, nonane and/or decane, or an isomer or mixture of

isomers of hexane, heptane and/or octane, the percentages being expressed relative to the total weight of the dissolution solvent (100% being the maximum).

Very preferably, the extraction solvent used in sub-step b3), when it is integrated into the process according to the invention, is of the same nature as the dissolution solvent used in step a), optionally in a different physical state (for example the extraction solvent in supercritical form relative to the dissolution solvent in liquid form), so as to facilitate the management of the solvents and in particular their purification and their recycling in particular into the dissolution step a) and optionally into the extraction sub-step b3). Another advantage of using identical dissolution and extraction solvents, in identical or different physical states, is, in addition to facilitating the management of the solvents (i.e. in particular the recovery, treatment and recycling of the solvents used in the process), that of limiting the energy consumptions and the costs generated in particular by the treatment and purification of the solvents.

The extraction section(s) of sub-step b3) may comprise one or more items of extraction equipment, enabling the placing in contact with the extraction solvent, and/or separation equipment for recovering at least one spent solvent, in particular charged with impurities, and an extracted polymer solution. These items of equipment are well known to those skilled in the art: they are, for example, stirred reactors, static mixers, decanting mixers, two-phase or three-phase separating vessels, co-current or counter-current washing columns, plate columns, stirred columns, packed columns, pulsed columns, etc., each type of equipment possibly comprising one or more items of equipment used alone or in combination with equipment of another type.

According to a preferred embodiment of b3), the extraction is performed in a counter-current extraction column. In this preferred embodiment, the extraction solvent is advantageously injected into the upper part of the column, preferably into the upper half, preferably the upper third, of the column (the upper part of the column meaning the part closest to the column head), on the one hand, and the polymer solution which feeds sub-step b3) is injected into the lower part of the column, preferably into the lower half, preferably the lower third, of the column (the lower part of the column meaning the part closest to the bottom of the column), on the other hand. According to this embodiment, it is possible to recover at least one extracted polymer solution, preferably at the top of the column, and a used solvent, in particular charged with impurities, preferably at the bottom of the column. The streams at the counter-current extraction column inlet and/or outlet may be divided at several injection points and/or withdrawal points along the column.

According to another embodiment of b3), the extraction is performed in a mixer-decanter which advantageously comprises a stirred mixing zone for placing in contact the extraction solvent and the polymer solution which feeds sub-step b3), and a decantation zone making it possible to recover an extracted polymer solution, on the one hand, and a used solvent, on the other hand.

Advantageously, the extraction sub-step b3) is performed under temperature and pressure conditions that are different from the temperature and pressure conditions of the dissolution step a).

According to a preferred embodiment, when it is incorporated into the treatment process, the extraction sub-step b3) includes a liquid/liquid extraction section. Preferably, said liquid/liquid extraction section is operated at a temperature of between 100°C and 300°C, preferably between 150°C and 250°C and at a pressure of between 0.1 and 100.0 MPa absolute, preferably between 1.0 and 25.0 MPa absolute, preferentially between 1.0 and 18.0 MPa absolute and very preferably between 1.5 and 15.0 MPa absolute. In any case, in this embodiment, the temperature and pressure conditions are adjusted so that the extraction solvent is in liquid form, the dissolution solvent preferably also being in liquid form. Very advantageously, the liquid/liquid extraction, in particular when the extraction solvent is the same as the dissolution solvent, is performed under temperature and pressure conditions that are different from the dissolution conditions achieved in step a), in particular at a temperature above the dissolution temperature and/or at a pressure below the dissolution pressure, so as thus to be in a two-phase zone of the corresponding polymer-solvent mixture diagram.

According to another preferred embodiment, the extraction sub-step b3) includes a section for extraction under particular temperature and pressure conditions in which the extraction solvent is advantageously at least partly in supercritical form. Such an extraction may be referred to as supercritical extraction. In this embodiment, the extraction is performed by placing the polymer solution which feeds b3) in contact with an extraction solvent which is at least partly, preferably totally, in supercritical form (preferably at least 50% by weight, preferentially at least 70% by weight, preferably at least 90% by weight of the extraction solvent is in supercritical form). Such a supercritical extraction sub-step b3) advantageously allows efficient purification of the polymer solution, in particular due to the very high affinity of the organic impurities, for instance some of the additives, including certain colorants, plasticizers, etc., for the supercritical phase. The use of an extraction solvent in supercritical form also makes it possible to create a substantial density difference between the supercritical phase and the polymer solution in liquid form, which facilitates separation by decantation between the supercritical phase advantageously charged with impurities, and the

liquid phase which comprises the targeted thermoplastics, and this consequently contributes towards the purification of the polymer solution.

In this other preferred embodiment, sub-step b3) uses an extraction solvent comprising at least 80% by weight, preferentially at least 95% by weight, preferably 98% by weight of at least one aliphatic paraffinic hydrocarbon-based compound (or alkane) (100% being the maximum, the percentages being expressed relative to the total weight of the extraction solvent) having a critical temperature preferably between 95 and 350°C, preferentially between 130 and 320°C, preferably between 180 and 300°C.

Advantageously, the supercritical extraction sub-step b3) of this other preferred embodiment is performed at a temperature between 100°C and 350°C, preferably between 130°C and 320°C, preferably between 180°C and 280°C, and at a pressure preferably between 2.0 and 100.0 MPa absolute, preferably between 2.0 and 25.0 MPa absolute, preferentially between 2.0 and 18.0 MPa absolute, very preferably between 2.7 and 15.0 MPa absolute and very preferably between 3.0 and 7.5 MPa absolute, or even between 3.0 and 5.5 MPa absolute. In any case, in this embodiment, the temperature and pressure conditions are adjusted, in particular in an adjustment section implemented in the extraction sub-step b3) upstream of the extraction section, so that the extraction solvent is at least partly in the supercritical state in the extraction section.

In a particular embodiment, the extraction sub-step b3) involves supercritical extraction and the extraction solvent is of the same nature as the dissolution solvent, apart from the fact that the extraction solvent is at least partly in supercritical form. In this case of supercritical extraction, the dissolution solvent may become at least partly in supercritical form, advantageously optimizing the decantation during the extraction step, more particularly at each extraction phase or plateau, between the liquid phase and the supercritical phase, which thus makes it possible to maximize the purification.

Advantageously, at the end of the extraction sub-step b3), the spent solvent obtained is in particular charged with soluble impurities. It may be retreated in an organic treatment section making it possible, on the one hand, to at least partly separate out the impurities and to purify the solvent to obtain a purified extraction solvent, and on the other hand to recycle at least a portion of the purified extraction solvent to the inlet of b3), and/or to the inlet of the dissolution step a) in the case where the dissolution solvent and the extraction solvent are of identical nature. The spent solvent may be treated according to any method known to those skilled in the art, for instance one or more methods from among distillation, evaporation, extraction, adsorption, crystallization and precipitation of insoluble matter, or by purging.

Adsorption sub-step b4)

The treatment process according to the invention may comprise an adsorption sub-step b4), for obtaining a refined polymer solution. The refined polymer solution obtained from sub-step b4) advantageously comprises the targeted thermoplastic polymers, in particular the targeted polyolefins, dissolved in the dissolution solvent. When it is incorporated into the process according to the invention, the adsorption sub-step b4) is advantageously performed by bringing the polymer solution which feeds it into contact with one or more adsorbents.

When it is incorporated into the process according to the invention, the adsorption sub-step b4) is preferably performed in the purification step b), upstream of the solvent-polymer separation step c). It may, however, be performed during the dissolution step a), by introducing adsorbent particles as a mixture with the crude polymer solution, said adsorbent particles being removed during the purification step b) and possibly during a sub-step b1) of separating out the insoluble matter or during a washing sub-step b2). The adsorption sub-step b4) may also be performed during the purification step b), preferably downstream of a sub-step b1) of separating out the insoluble matter and optionally upstream or downstream of an extraction sub-step b3).

The adsorption sub-step b4) advantageously includes an adsorption section operated in the presence of at least one adsorbent, which is preferably solid, and in particular in the form of a fixed bed, an entrained bed (or slurry, i.e. in the form of particles introduced into the stream to be purified and entrained with this stream) or in the form of an ebullated bed, preferably in the form of a fixed bed or an entrained bed, or in the form of adsorbent particles dispersed in the polymer solution. The adsorbent(s) used in sub-step b4) are preferably an alumina, a silica, a silica-alumina, an activated carbon, a decolourizing earth, or mixtures thereof, preferably an activated carbon, a bleaching earth or mixtures thereof, preferably in the form of a fixed bed or an entrained bed, the circulation of the streams possibly being ascending or descending through said bed.

Advantageously, when it is incorporated into the process, the adsorption sub-step b4) is performed at a temperature of between 100°C and 300°C, preferably between 150°C and 250°C, and a pressure of between 0.1 and 100.0 MPa absolute, preferably between 1.0 and 25.0 MPa absolute, preferentially between 1.0 and 18.0 MPa absolute and very preferably between 1.5 and 15.0 MPa absolute. Very advantageously, the adsorption sub-step b4) is performed under the dissolution temperature and pressure conditions, i.e. at the dissolution temperature and dissolution pressure achieved in step a), optionally with a lowered pressure, preferably from 0.01 to 10.0 MPa, preferably from 0.1 to 5.0 MPa due to the pressure drops experienced between step a) and sub-step b4). Preferably, in sub-step b4), the hourly space

velocity (or HSV), which corresponds to the ratio between the volume flow rate of the polymer solution which feeds b4) and the volume of adsorbent, advantageously operating in b4) is between 0.05 and 10 h⁻¹, preferentially between 0.1 and 5.0 h⁻¹.

According to a particular embodiment of sub-step b4), the adsorption section may comprise one or more fixed beds of adsorbent, for example in the form of adsorption columns, preferably at least two adsorption columns, preferentially between two and four adsorption columns, containing said adsorbent(s). When the adsorption section comprises two adsorption columns, one operating mode may be that referred to as “swing” operating according to the dedicated terminology, in which one of the columns is on-line, i.e. in service, while the other column is in reserve. When the adsorbent of the on-line column is spent, this column is isolated, while the column in reserve is brought on-line, i.e. in service. The spent adsorbent can then be regenerated *in situ* and/or replaced with fresh adsorbent so that the column containing it can once again be brought on-line once the other column has been isolated.

Another mode of functioning of this particular embodiment of b4) is to have at least two adsorbent columns functioning in series. When the adsorbent of the column placed at the head is spent, this first column is isolated and the spent adsorbent is regenerated *in situ* or replaced with fresh adsorbent. The column is subsequently brought back on-line in the last position, and so on. This operation is referred to as permutable mode, or as PRS for permutable reactor system or else as “lead and lag”. The combination of at least two adsorption columns makes it possible to overcome the possible and potentially rapid poisoning and/or clogging of the adsorbent due to the combined action of the impurities, of the contaminants and of the insoluble matter that may be present in the stream to be treated. The reason for this is that the presence of at least two adsorption columns facilitates the replacement and/or regeneration of the adsorbent, advantageously without stoppage of the process, also making it possible to control the costs and to limit the consumption of adsorbent.

Step c) of solvent-polymer separation

According to the invention, the process comprises a solvent-polymer separation step c), to obtain at least one stream of purified thermoplastic polymers, more particularly at least one stream of purified polyolefins and preferably at least one solvent stream. This step c) is downstream of the purification step b). It is advantageously fed with the purified polymer solution obtained from purification step b).

The solvent-polymer separation step c) is directed towards at least partly, preferably predominantly or even totally, separating out the solvent(s), in particular the dissolution

solvent, contained in the purified polymer solution which feeds step c), so as to recover the targeted thermoplastics which have been at least partly, preferably totally, stripped of the impurities and of the dissolution solvent and preferably also of the other solvent(s) optionally used in particular in step b) of the process (i.e. the extraction solvent and/or the dense solution). The term "predominantly" should be understood as meaning at least 50% by weight, preferentially preferably at least 70% by weight, preferably at least 90% by weight, very preferably at least 95% by weight, relative to the weight of the solvent(s) contained in the purified polymer solution which feeds step c), in particular of the dissolution solvent and optionally of the extraction solvent and/or the dense solution contained in the purified polymer solution which feeds step c).

Thus, the solvent-polymer separation step c) includes a gas-liquid separation section or a plurality of gas-liquid separation sections operating in series. The expression "a plurality of gas-liquid separation sections" means, according to the present description, at least two gas-liquid separation sections, and preferably between two and ten, preferentially between two and five, for example three or four, gas-liquid separation sections. Preferably, the solvent-polymer separation step c) includes at least two, preferentially between two and ten, very preferentially between two and five, for example three or four, successive gas-liquid separation sections. In other words, the solvent-polymer separation step c) preferably includes N gas-liquid separation sections, N being an integer greater than or equal to two, preferably between two and ten, preferentially between two and five, N being for example three or four.

The principle of separation in said gas-liquid separation section or in the gas-liquid separation sections of the series is based on the evaporation, at least in part, of the solvent, in particular the dissolution solvent, present in the polymer solution which feeds said section or each of said sections; and said solvent (or the fraction of said solvent) then in gaseous form is separated from the polymer solution which is itself in liquid form.

Thus, the gas-liquid separation section or each of the gas-liquid separation sections produces a gaseous effluent, which advantageously comprises solvent, in particular dissolution solvent, in gaseous form, and a liquid effluent which advantageously comprises the targeted thermoplastics possibly dissolved in the residual dissolution solvent. When the liquid effluent comprises residual solvent, in particular residual dissolution solvent, said targeted thermoplastics are dissolved in the residual solvent and the liquid effluent thus corresponds to a polymer solution. Very advantageously, the liquid effluent from said gas-liquid separation section or from the last gas-liquid separation section of the series preferably comprises at most 5% by weight, preferentially at most 1.00% by weight, very preferentially at most 0.10% by weight, or even at most 500 ppm by weight of solvent, relative to the total

weight of said liquid effluent, and advantageously constitutes said stream of purified thermoplastic polymers.

The purified polymer solution obtained from the purification step b) is fed into said gas-liquid separation section or into the first gas-liquid separation section of the series. When step c) involves a plurality of gas-liquid separation sections, the liquid effluent from the preceding section feeds into the subsequent section. In other words, when step c) involves N successive gas-liquid separation sections, with N being an integer greater than or equal to two, preferably between two and ten, preferentially between two and five, for example N being three or four:

the purified polymer solution obtained from of the purification step b) feeds into the first gas-liquid separation section of the series, which produces a first gaseous effluent and a first liquid effluent;

the first liquid effluent obtained from the first gas-liquid separation section feeds into the second gas-liquid separation section of the series, which produces a second gaseous effluent and a second liquid effluent;

the second liquid effluent obtained from the second gas-liquid separation section feeds into the third gas-liquid separation section of the series which produces a third gaseous effluent and a third liquid effluent;

and so on up to the Nth section which is fed with the (N-1)th liquid effluent obtained at the outlet of the (N-1)th gas-liquid separation section of the series and which produces an Nth gaseous effluent and an Nth liquid effluent,

the Nth liquid effluent obtained from the Nth gas-liquid separation section advantageously constitutes the stream of purified thermoplastic polymers.

The gaseous effluent produced by said gas-liquid separation section or the gaseous effluents produced by the gas-liquid separation sections of the series is/are recovered and may be, totally or partially, purged and/or purified and/or fractionated and/or recycled, directly or after purification, into step a) and/or optionally into step b). For example, the gaseous effluent produced by said gas-liquid separation section or the gaseous effluents produced by the gas-liquid separation sections of the series can be completely purged; or partially purged and partially recycled directly into step a); or completely recycled directly into step a) with a total purge at a regular frequency and for a fixed time; or at least partially purified and then recycled into step a). According to another embodiment, at least one part of the gaseous effluent produced by said gas-liquid separation section or the gaseous effluents produced by the gas-liquid separation sections of the series may be recovered and sent to the purification

step b) and may be used as a cleaning solvent for at least one item of purification equipment, for example to clean filters.

Said gas-liquid separation section or each of the gas-liquid separation sections, implemented in step c), is operated at an inlet temperature (i.e. temperature at the inlet of said section or of each section) of between 100°C and 300°C, preferably between 110°C and 250°C, preferably between 150°C and 250°C, and at a pressure lower than the pressure in step b) and preferably than the pressure at the outlet of step b), in particular at a pressure of less than 100.0 MPa absolute, preferably less than 25.0 MPa absolute, preferentially less than 18.0 MPa absolute, preferably less than 15.0 MPa absolute. Preferably, in the gas-liquid separation section or in each of the gas-liquid separation sections, the pressure is greater than or equal to 0.000005 MPa absolute (i.e. greater than or equal to 5 Pa absolute), in particular greater than or equal to 0.00001 MPa absolute (i.e. greater than or equal to 10 Pa absolute), in particular greater than or equal to 0.0001 MPa absolute (i.e. greater than or equal to 0.1 kPa absolute), more particularly greater than or equal to 0.0005 MPa absolute (i.e. greater than or equal to 0.5 kPa absolute). Very advantageously, the temperature is adjusted, in the gas-liquid separation section or in each of the gas-liquid separation sections, so as to have an operating temperature above or equal to the evaporation temperature of the solvent, in particular the dissolution solvent, and advantageously above or equal to the melting point of the targeted thermoplastics, at the operating pressure of the gas-liquid separation section under consideration.

When step c) implements a plurality of gas-liquid separation sections, the pressure of the subsequent section is lower than that of the preceding section. In other words, when step c) implements N successive gas-liquid separation sections, N being an integer greater than or equal to two, preferably between two and ten, preferentially between two and five, for example N being chosen from three and four, the pressure of the second section of the series is lower than that of the first section of the series, the pressure of the third section of the series is lower than that of the second section of the series, and so on up to the Nth section in which the pressure is lower than the pressure of the (N-1)th section of the series, the pressure of the first section of the series being lower than the pressure of step b), preferably the pressure at the outlet of step b). In particular, the first gas-liquid separation section may be operated at an inlet temperature of between 100°C and 300°C, preferably between 110°C and 275°C, and at a pressure of less than 100.0 MPa absolute, preferably less than 25.0 MPa absolute, preferentially less than 15.0 MPa absolute, and advantageously greater than or equal to 0.0008 MPa absolute (i.e. greater than or equal to 0.8 kPa absolute or greater than or equal to 8 mbar absolute); while the Nth section may be operated at an inlet temperature of between 100°C and 300°C, preferably between 110°C

and 275°C, and at a pressure of between 0.000005 and 1.00 MPa absolute (i.e. between 5 Pa absolute and 1.00 MPa absolute or between 0.05 mbar and 10.0 bar), preferably between 0.00001 and 1.00 MPa absolute (i.e. between 10 Pa absolute and 1.00 MPa absolute, or between 0.1 mbar and 10.0 bar), preferably between 0.0001 and 1.00 MPa absolute (i.e. between 1 mbar and 10.0 bar), preferably between 0.0001 and 0.10 MPa absolute (i.e. between 1 mbar and 1.0 bar), preferentially between 0.0005 and 0.10 MPa absolute (i.e. between 5 mbar and 1.0 bar), preferentially between 0.0005 and 0.050 MPa absolute (i.e. between 5 mbar and 0.50 bar), preferentially between 0.0005 and 0.0050 MPa absolute (i.e. between 5 mbar and 50 mbar), very preferentially between 0.0005 and 0.0020 MPa absolute (i.e. between 5 mbar and 20 mbar) and very preferably between 0.0008 and 0.0010 MPa absolute (i.e. between 8 mbar and 10 mbar). In this particular case, the pressure in each intermediate section, located between the first and Nth section, where applicable, i.e. when it is/they are used, is adjusted in a decreasing manner and between the pressure of the first section and the pressure of the last section.

According to a very particular embodiment, the targeted thermoplastic is polypropylene and the dissolution solvent is an isomer or a mixture of isomers of hexane, heptane and/or octane. In this particular embodiment, the dissolution step a) is performed at a dissolution temperature of between 150°C and 250°C, preferably between 160°C and 225°C, preferentially between 170°C and 200°C, and at a dissolution pressure of between 1.0 and 25.0 MPa absolute, preferably between 1.0 and 12.0 MPa absolute, preferentially between 1.5 and 6.0 MPa absolute, preferably between 2.0 and 5.0 MPa absolute. According to this particular embodiment, step b) is performed within the same temperature and pressure ranges and makes it possible to obtain a purified polymer solution comprising the targeted polypropylene, which is sent to the solvent-polymer separation step c). In this embodiment, step c) makes use, for example, of four successive gas-liquid separation sections, in which:

- the first section is preferably operated at an inlet temperature of between 165°C and 275°C, preferentially between 170°C and 275°C, and at a pressure of between 0.5 and 4.0 MPa, preferentially between 0.5 and 2.0 MPa absolute, preferably between 0.5 and 1.0 MPa absolute,
- the fourth section is preferably operated at an inlet temperature of between 165°C and 275°C, preferentially between 170°C and 275°C, and at a pressure of between 0.000005 and 0.0050 MPa absolute (i.e. between 0.05 and 50 mbar), preferably between 0.00001 and 0.0050 MPa absolute (i.e. between 0.1 and 50 mbar), preferentially between 0.0001 and 0.0050 MPa absolute (i.e. between 1 and 50 mbar), very preferentially between 0.0005 and 0.0020 MPa absolute (i.e. between 5 and 20 mbar), very preferably between 0.0008 and 0.0010 MPa absolute (i.e. between 8 and 10 mbar), or at a pressure of between 0.000005

and 1.0 MPa absolute (i.e. between 0.05 mbar and 10 bar) in the presence of a stripping agent introduced into the fourth gas-liquid separation section;

- the second and third gas-liquid separation sections (i.e. the intermediate gas-liquid separation sections) are operated at an inlet temperature of between 165°C and 275°C, preferentially between 170°C and 275°C, and at a pressure lower than that of the first gas-liquid separation section and higher than that of the fourth gas-liquid separation section, and more particularly: for the second gas-liquid separation section, at a pressure lower than the pressure of the first gas-liquid separation section and higher than that of the third gas-liquid separation section; and for the third gas-liquid separation section, at a pressure lower than the pressure of the second gas-liquid separation section and higher than that of the fourth gas-liquid separation section.

According to another particular embodiment, the targeted thermoplastic is polyethylene and the dissolution solvent is preferably an isomer or a mixture of isomers of butane, pentane, hexane, heptane and/or octane. In this particular embodiment, the dissolution step a) is performed at a dissolution temperature of between 120°C and 300°C, preferably between 130°C and 275°C, preferentially between 150°C and 250°C, and at a dissolution pressure of between 0.1 and 100.0 MPa absolute, preferably between 1.0 and 25.0 MPa absolute, preferentially between 1.5 and 18.0 MPa absolute, preferably between 2.0 and 15.0 MPa absolute. Step b) is performed within the same temperature and pressure ranges and makes it possible to obtain a purified polymer solution comprising the targeted polyethylene, which is sent to the solvent-polymer separation step c). In this other particular embodiment, step c) makes use, for example, of four successive gas-liquid separation sections, in which:

- the first section is preferably operated at an inlet temperature of between 130°C and 300°C, preferentially between 150°C and 275°C, and at a pressure greater than or equal to 0.1 MPa absolute and lower than the pressure at the outlet of step b), the temperature and pressure being advantageously adjusted so as to evaporate a portion of the dissolution solvent, present in the purified polymer solution which feeds into the first section;

- the fourth section is preferably operated at an inlet temperature of between 130°C and 300°C, preferentially between 150°C and 275°C, and at a pressure of between 0.000005 and 0.0500 MPa absolute (i.e. between 0.05 and 500 mbar), preferably between 0.00001 and 0.0100 MPa absolute (i.e. between 0.1 and 100 mbar), preferentially between 0.0001 and 0.0050 MPa absolute (i.e. between 1 and 50 mbar);

- the second and third gas-liquid separation sections (i.e. the intermediate gas-liquid separation sections) are operated at an inlet temperature of between 130°C and 300°C, preferentially between 150°C and 275°C, and at a pressure lower than that of the first gas-

liquid separation section and higher than that of the fourth gas-liquid separation section, and more particularly: for the second gas-liquid separation section, at a pressure lower than the pressure of the first gas-liquid separation section and higher than that of the third gas-liquid separation section; and for the third gas-liquid separation section, at a pressure lower than
 5 the pressure of the second gas-liquid separation section and higher than that of the fourth gas-liquid separation section.

Said gas-liquid separation section(s) may include any type of device known to those skilled in the art for separating gas and liquid, possibly accompanied by means for adjusting the temperature and pressure, for example heating means, means for adjusting and regulating
 10 the pressure above atmospheric pressure, means for adjusting and regulating the pressure below atmospheric pressure (to obtain a vacuum), etc.; mechanical means for moving and contacting the gas and liquid phases. For example, said gas-liquid separation section(s) may implement one or more items of equipment chosen from: a separating vessel, a column, a distillation column, a stripper, equipment comprising internals and/or packing facilitating
 15 separation between the gas and the liquid, an evaporator, a thin-film evaporator, a wiped-film evaporator, a falling-film evaporator, a paddle evaporator, a rotating disc reactor or column, a reactor, a stirred reactor, an extruder, a kneader reactor, a devolatilizer. According to a very particular embodiment, said gas-liquid separation section(s) may implement a gas-liquid separator comprising:

- 20 - a chamber comprising a cylindrical upper part and a cylindrical lower part extended by a base of decreasing cross section, said lower part advantageously comprising a liquid guard zone at the bottom of the chamber,
- an inlet pipe, for feeding said separator with a gas/liquid stream, said inlet pipe opening at one end into the lower part of said chamber and said end being advantageously bent (i.e. the
 25 internal end being advantageously bent),
- an outlet pipe bottom of said chamber, to discharge a separated liquid stream from said gas-liquid separator,
- a gas-liquid separation system which may be:
 - a cyclone with a cylindroconical body, internal to said chamber, and comprising
 30 a tangential inlet tube for feeding said cyclone with a gas/liquid mixture, said tube being located in the upper part of said chamber,

an outlet tube for discharging a separated gas stream, said outlet tube located at the top of said cylindroconical body, said outlet tube opening outside of the chamber of the gas-liquid separator, and

an opening at the base of said cylindroconical body, said opening being connected to a dipleg for a liquid flow, said dipleg opening into said liquid guard zone at the bottom of the chamber of said gas-liquid separator; and/or

- a gas-liquid separation device equipped with a helical spiral located in the upper part of said chamber, said gas-liquid separation device being capped by an upper cap which comprises at its upper end a gas discharge duct and at its lower end a vertical duct concentric with the intake duct allowing the separated liquid to return to the liquid guard zone at the bottom of the chamber of said gas-liquid separator;

- optionally means for injecting an entraining agent and/or inert gas stream.

10 According to this particular embodiment, the lower part of the chamber, and more particularly the liquid guard zone at the bottom of the chamber, may be equipped with a stirrer. Still according to this particular embodiment, a pump, in particular a pump capable of entraining viscous fluids, also referred to as a melt pump, can be used at the external end (with respect to said gas-liquid separator) of said outlet pipe located in the bottom of the chamber.

15 An entraining agent (or stripping agent) may optionally be introduced into the gas-liquid separation section or the last (i.e. the Nth) gas-liquid separation section of the series, to aid the vaporization of the residual solvent present in the polymer solution at the inlet to said last section. The addition of an entraining agent thus enables optimization of the solvent-polymer separation in the last gas-liquid separation section. It enables very low residual solvent
20 contents to be achieved in the stream of purified thermoplastics, in particular less than or equal to 5% by weight, less than or equal to 1.00% by weight, preferably less than or equal to 0.10% by weight, preferentially less than or equal to 500 ppm by weight of solvent relative to the total weight of the purified thermoplastics stream, without the need to achieve a high vacuum in the last section, i. e. without reaching a pressure of between 0.000005 and
25 1.00 MPa absolute, in particular between 0.00001 and 1.00 MPa absolute, in particular between 0.0001 and 1.00 MPa absolute, more particularly between 0.0005 and 0.0020 MPa absolute, or even very particularly between 0.0008 and 0.0010 MPa absolute. The entraining agent optionally introduced is a compound that is lighter than the dissolution solvent, i.e. a compound with a boiling point lower than that of the dissolution solvent (at atmospheric
30 pressure), for example water, nitrogen or hydrogen. Preferably, the amount of entraining agent optionally introduced represents between 10% and 0.1% by weight of entraining agent relative to the targeted thermoplastics.

Optionally, a stream of inert gas, preferably a stream of nitrogen, may be introduced into the gas-liquid separation section or the first gas-liquid separation section of the series, to aid the
35 vaporization and thus the removal of the solvent, in particular the dissolution solvent, present

in the purified polymer solution which is fed into step c). The presence of inert gas modifies the phase diagram. The presence of the inert gas, in particular the presence of nitrogen, may thus promote the evaporation of the solvent, in particular of the dissolution solvent, present in the purified polymer solution which feeds step c), and thus make it possible to limit the

5 operating temperatures in said section or first section, while at the same time optimizing the evaporation of the solvent. At the outlet of the gas-liquid separation section or the first gas-liquid separation section in the series, the inert gas is then advantageously in admixture with the gaseous dissolution solvent in the gaseous effluent. The presence of the inert gas, in particular the presence of nitrogen, may also modify the phase diagram in such a way that

10 the solvent, in particular the dissolution solvent, present in the purified polymer solution is at least partly in supercritical form. In this situation, the fraction of the solvent, in particular the dissolution solvent, which is in supercritical form, may be separated from the polymer solution by density difference, for example by decantation, in particular in a settling vessel. The presence of the inert gas, in particular the presence of nitrogen, may also modify the

15 phase equilibrium of the purified polymer solution, which may demix and become two-phase with a first liquid phase comprising the thermoplastics and a liquid phase composed essentially of solvent, in particular dissolution solvent. In the case of the presence of a stream of inert gas, in particular a stream of nitrogen, said stream of inert gas is introduced in an amount such that the weight ratio between the flow rate of the stream of inert gas and the

20 flow rate of the purified polymer solution is between 0.000001 and 1.00, preferably 0.0001 and 0.50.

Optionally, the solvent-polymer separation step c) may comprise an intermediate separation upstream of the successive gas-liquid separation(s). Thus, step c) may include an

25 intermediate separation section located upstream of the successive gas-liquid separation section(s). This intermediate separation may be a liquid-liquid separation, which then advantageously includes an intermediate liquid-liquid separation section, or a supercritical-liquid separation, which then advantageously includes an intermediate supercritical-liquid separation section. The optional intermediate liquid-liquid or supercritical-liquid separation section is advantageously fed with the purified polymer solution from step b), and optionally

30 with a stream of inert gas, in particular a stream of nitrogen. This allows a liquid phase to be produced, which comprises the targeted thermoplastics in particular dissolved in the residual dissolution solvent, and a second liquid phase or a supercritical phase which comprises dissolution solvent, in the liquid or at least partially supercritical state, and which is advantageously low in targeted thermoplastics, preferably which contains less than 5% by

35 weight, preferably less than 1.00% by weight, preferentially less than 0.10% by weight or even less than 500 ppm by weight of targeted thermoplastics relative to the total weight of

said second liquid phase or supercritical phase, or even which is free of targeted thermoplastics. Said optional inert gas stream may specifically assist in the demixing of the purified polymer solution to form a two-phase liquid system, or aid at least some of the dissolution solvent to pass to the supercritical state.

- 5 When an intermediate liquid-liquid separation is incorporated in step c), said intermediate liquid-liquid separation advantageously comprises (i) adjustment of the temperature and/or pressure so as to obtain demixing of the purified polymer solution, and then (ii) separation by density difference, in particular by decantation, of a first liquid phase which comprises the targeted thermoplastics in particular dissolved in the residual dissolution solvent, and a
- 10 second liquid phase, which is low in targeted thermoplastics, i.e. which comprises less than 5% by weight, preferably less than 1.00% by weight, preferentially less than 0.10% by weight, or even less than 500 ppm by weight of targeted thermoplastics relative to the total weight of said second liquid phase. Thus, when step c) comprises an intermediate liquid-
- 15 liquid separation, the temperature and/or pressure are adjusted in the intermediate liquid-liquid separation section, so as to form a two-phase system from the purified polymer solution, optionally in the presence of an inert gas stream. Preferably, the temperature in the intermediate liquid-liquid separation section is adjusted to a value below than the critical temperature of the dissolution solvent (but above the melting temperature of the targeted thermoplastics). Preferably, the pressure in the intermediate liquid-liquid separation section is
- 20 adjusted to a value less than or equal to the pressure of the bubble point of the dissolution solvent at the operating temperature, preferably adjusted to a value between a pressure 1.0 MPa less than the bubble point pressure or equal to said bubble point pressure of the dissolution solvent at the operating temperature.

- When an intermediate supercritical-liquid separation is incorporated into step c), said
- 25 intermediate supercritical-liquid separation preferably comprises (i) a temperature and/or pressure adjustment in the intermediate supercritical-liquid separation section, optionally in the presence of an inert gas stream, so that the dissolution solvent is at least partially in the supercritical state, and then (ii) separation by density difference, in particular by decantation, of a liquid phase which comprises the targeted thermoplastics in particular dissolved in the
- 30 residual dissolution solvent, and a supercritical phase which comprises dissolution solvent in the supercritical state. The optional intermediate supercritical-liquid separation may in particular be incorporated into step c) when the dissolution solvent is sufficiently light, in particular when the dissolution solvent has a boiling point (at atmospheric pressure, in particular at 0.1 MPa) of between -50°C and 100°C, preferably between -50°C and 70°C,
- 35 preferentially between -45°C and 50°C.

The liquid phase which comprises the targeted thermoplastics obtained from the optional intermediate liquid-liquid or supercritical-liquid separation section feeds into the gas-liquid separation section or the first gas-liquid separation section, advantageously in place of the purified solution.

- 5 For example, the targeted thermoplastic is polyethylene and the dissolution solvent is preferably an isomer or a mixture of isomers of butane, pentane, hexane, heptane and/or octane. In this particular case, the dissolution step a) is performed at a dissolution temperature of between 120°C and 300°C, preferably between 130°C and 275°C, preferentially between 150°C and 250°C, and at a dissolution pressure of between 0.1 and 100.0 MPa absolute, preferably between 1.0 and 25.0 MPa absolute, preferentially between 1.5 and 18.0 MPa absolute, preferably between 2.0 and 15.0 MPa absolute. Step b) is performed within the same temperature and pressure ranges and makes it possible to obtain a purified polymer solution comprising the targeted polyethylene, which is sent to the solvent-polymer separation step c). In this particular case, step c) may implement at least one 15 intermediate liquid-liquid or supercritical-liquid separation section and two or three successive gas-liquid separation sections, for example as follows:
 - the intermediate liquid-liquid or supercritical-liquid separation section, preferably supercritical-liquid separation section, is operated at an inlet temperature of between 130°C and 300°C, preferentially between 150°C and 275°C, and at a pressure greater than or equal 20 to 3.0 and 10.0 MPa absolute, preferably between 3.0 and 100.0 MPa absolute, the temperature and pressure being advantageously adjusted so as to obtain a two-phase liquid-liquid system or so as to have at least part of the dissolution solvent, present in the purified polymer solution which feeds the first section, in the supercritical state; said intermediate liquid-liquid or supercritical-liquid separation section thus produces a liquid effluent which 25 comprises polyethylene and which is sent to the first gas-liquid separation section, and another liquid effluent or a supercritical effluent, preferably a supercritical effluent, which comprises dissolution solvent;
 - the first gas-liquid separation section is operated at an inlet temperature of between 130°C and 300°C, preferentially between 150°C and 275°C, and at a pressure lower than or equal 30 to 0.1 MPa absolute and lower than the pressure at the outlet of the intermediate liquid-liquid or supercritical-liquid separation section;
 - the last gas-liquid separation section is operated at an inlet temperature of between 130°C and 300°C, preferentially between 150°C and 275°C, and at a pressure of between 0.000005 and 0.0500 MPa absolute (i.e. between 0.05 and 500 mbar), preferably between 0.00001

and 0.0100 MPa absolute (i.e. between 0.1 and 100 mbar), preferentially between 0.0001 and 0.0050 MPa absolute (i.e. between 1 and 50 mbar);

- the optional intermediate gas-liquid separation section is operated at an inlet temperature of between 130°C and 300°C, preferentially between 150°C and 275°C, and at a pressure lower than that of the first gas-liquid separation section and higher than that of the last gas-liquid separation section.

Optionally, at least one additive may be introduced in step c), and/or optionally upstream of step c), in particular upstream of the dissolution step a), in the dissolution step a) or in step b) and more particularly in a sub-step b1) for separating out the insoluble matter. For example, an antioxidant may be introduced in step c), and/or optionally upstream of step c), for example upstream of the dissolution step a), in the dissolution step a) or even in step b) and more particularly in a sub-step b1) for separating out the insoluble matter, so as to limit or even prevent any degradation of the targeted thermoplastics. A person skilled in the art will know how to choose said at least one additive, in particular said antioxidant, depending on the targeted thermoplastics. For example, the antioxidant may be chosen from the compounds sold under the Irganox® and Irgafos® brand names, and in particular from the following commercial compounds: Irganox® 1010, Irgafos® 168, Oxidized Irgafos® 168. A person skilled in the art will also know how to adjust the amount of said at least one additive, in particular of said antioxidant to be introduced, depending on the targeted thermoplastics and the desired properties. For example, the antioxidant may be introduced so as to adjust the content of said antioxidant to between 100 and 10 000 ppm by weight, preferably between 500 and 5000 ppm by weight of antioxidant relative to the weight of the targeted thermoplastics. In the case where an additive, in particular an antioxidant, is introduced in step c), and when step c) includes a single gas-liquid separation section, said additive, in particular antioxidant, is preferably introduced upstream of said gas-liquid separation section, more particularly into the purified polymer solution obtained from b) or optionally into the liquid phase obtained from the intermediate liquid-liquid or supercritical-liquid separation section optionally implemented upstream of said gas-liquid separation section. In the case where an additive, in particular an antioxidant, is introduced in step c), and when step c) includes several successive gas-liquid separation sections, said additive, in particular an antioxidant, is preferably introduced downstream of the first gas-liquid separation section of the series, in unit form or fractionally, more particularly in at least one of the liquid effluents produced by the gas-liquid separation sections of the series (including the first section), and preferably in one of the liquid effluents produced by one of the sections upstream of the last gas-liquid separation section of the series. In the case where an additive, in particular an antioxidant, is introduced in step c), and when step c) includes an intermediate liquid-liquid or

supercritical-liquid separation section and one or more successive gas-liquid separation sections, said additive, in particular an antioxidant, is preferably introduced downstream of said intermediate section, in unit form or fractionally, more particularly in the liquid phase obtained from said intermediate section and/or in the liquid effluent produced by the gas-liquid separation section or in at least one of the liquid effluents produced by the gas-liquid separation sections of the series (including the first section), and preferably in the liquid phase obtained from said intermediate section and/or in the liquid effluent produced by the gas-liquid separation section or in one of the liquid effluents produced by one of the sections upstream of the last gas-liquid separation section of the series.

Thus, the process according to the invention allows a stream of purified thermoplastics, and more particularly of purified polyolefins, to be obtained which has a very low content of residual solvent (in particular dissolution solvent), and in particular a content of less than or equal to 5% by weight, preferably less than or equal to 1.00% by weight, preferably less than or equal to 0.10% by weight, or even a content of less than or equal to 500 ppm by weight, relative to the total weight of the stream of purified thermoplastics. More particularly, the stream of purified thermoplastics, and more particularly of purified polyolefins, obtained from the process according to the invention has a volatile organic compound (VOC) content of less than or equal to 5% by weight, preferably less than or equal to 1.00% by weight, preferably less than or equal to 0.10% by weight, or even a content of less than or equal to 500 ppm by weight, relative to the total weight of the stream of purified thermoplastics. The VOC content gives a good indication of the solvent content and in particular of the residual solvent content in the stream of purified thermoplastics obtained.

Preferably, the volatile organic compound (VOC) content is determined by headspace (HS) gas chromatography coupled with mass spectrometry (MS) or with a flame ionization detector (FID), preferably coupled with mass spectrometry (MS).

The stream of purified thermoplastic polymers obtained from the process according to the invention also very advantageously has an impurity content of less than or equal to 5% by weight of impurities, preferably less than or equal to 1.0% by weight of impurities, preferentially a content of less than or equal to 0.5% by weight of impurities relative to the total weight of the stream of purified thermoplastics. The stream of purified thermoplastic polymers obtained from the process according to the invention can then be used in any application, for example as a replacement for the same polymers in virgin form.

Device

The present invention also relates to a device for treating a plastic feedstock to obtain a stream of purified thermoplastic polymers, comprising:

A) dissolution means for contacting and at least partially dissolving the plastic feedstock in a dissolution solvent, and producing a crude polymer solution, said dissolution means advantageously being any type of industrial equipment allowing said contacting and said dissolution, for example an extruder, static or dynamic mixer(s), and/or continuous stirred tank reactors (CSTR) equipped with suitable stirring system(s);

B) purification means for purifying the crude polymer solution and obtaining a purified polymer solution, said purification means advantageously being any type of industrial equipment that is capable of purifying the crude polymer solution, said purification means possibly comprising:

solid-liquid (or solid-liquid-liquid) separation means, said solid-liquid separation means advantageously being any type of industrial equipment for separating solids and one or two liquids, such as decantation, filtration, centrifugation and/or electrostatic separation equipment, to obtain a clarified polymer solution;

a washing device allowing the crude or clarified polymer solution to be placed in contact with a dense solution, in particular an aqueous solution, to obtain a washed polymer solution;

an extraction device allowing the crude or clarified or washed polymer solution to be placed in contact with an organic solvent in the liquid state or at least partially in the supercritical state, so as to obtain an extracted polymer solution; and/or

an adsorption device allowing the crude or clarified or washed or extracted polymer solution to be placed in contact with at least one adsorbent, in particular at least one adsorbent bed or adsorbent particles in divided form, and allowing the recovery of a refined polymer solution;

said clarified, washed, extracted or refined polymer solution constituting the purified polymer solution;

C) a solvent-polymer separation device, located downstream of said purification means, for separating the purified polymer solution into a stream of purified thermoplastic polymers and at least one solvent effluent advantageously comprising dissolution solvent,

characterized in that said solvent-polymer separation device comprises:

a gas-liquid separation section or a plurality of gas-liquid separation sections operating in series, preferably at least two, preferentially between two and ten, very preferentially between two and five, for example three or four, successive gas-liquid separation sections,

at least one system for controlling the pressure in said gas-liquid separation section or in each gas-liquid separation section of the series, so as to adjust the pressure in said gas-liquid separation section or each gas-liquid separation section of the series to a value lower

than the pressure at the outlet of the purification means, and when said solvent-polymer separation device comprises a plurality of gas-liquid separation sections, so as to adjust the pressure in the subsequent section to a value lower than that in the preceding section,

optionally, at least one system for controlling the temperature, in particular the inlet temperature, of said gas-liquid separation section or of each gas-liquid separation section of the series,

said gas-liquid separation section or each gas-liquid separation section of the series comprising a feed system, a liquid withdrawal system and a gas withdrawal system,

the feed system of said gas-liquid separation section or of the first gas-liquid separation section of the series being connected to at least one of the purification means and allowing purified polymer solution to be fed to said solvent-polymer separation device,

when said solvent-polymer separation device comprises a plurality of gas-liquid separation sections, the feed system of the subsequent section is connected to the liquid withdrawal system of the preceding section,

the liquid withdrawal system of said gas-liquid separation section or of the last gas-liquid separation section of the series making it possible to recover said stream of purified thermoplastic polymers,

the gas withdrawal system of said gas-liquid separation section or of each gas-liquid separation section of the series making it possible to recover said at least one solvent effluent which comprises the dissolution solvent, and it being possible for the gas withdrawal system of said section or of each section to optionally be connected directly or indirectly to devices for condensing, for purifying, for fractionating and/or for recycling solvent effluent(s) to said dissolution means and/or optionally to said purification means.

Said gas-liquid separation section(s) may implement any type of device, in particular any type of industrial equipment, known to those skilled in the art for separating gas and liquid, optionally accompanied by devices for adjusting the temperature, in particular the inlet temperature, and the pressure, for example heating equipment, equipment for adjusting and regulating the pressure above atmospheric pressure, equipment for adjusting and regulating the pressure below atmospheric pressure (to obtain a vacuum), etc.; equipment for moving and contacting the gas and liquid phases. For example, said gas-liquid separation section(s) may implement one or more items of equipment chosen from: a separating vessel, a column, a distillation column, a stripper, equipment comprising internals and/or packing facilitating separation between the gas and the liquid, an evaporator, a thin-film evaporator, a wiped-film evaporator, a falling-film evaporator, a paddle evaporator, a rotating disc reactor or column, a reactor, a stirred reactor, an extruder, a kneader reactor, a devolatilizer. According to a very

particular embodiment, said gas-liquid separation section(s) may implement a gas-liquid separator comprising:

- a chamber comprising a cylindrical upper part and a cylindrical lower part extended by a base of decreasing cross section, said lower part advantageously comprising a liquid guard zone at the bottom of the chamber,
- an inlet pipe, for feeding said separator with a gas/liquid stream, said inlet pipe opening at one end into the lower part of said chamber and said end being advantageously bent (i.e. the internal end being advantageously bent),
- an outlet pipe bottom of said chamber, to discharge a separated liquid stream from said gas-liquid separator,
- a gas-liquid separation system which may be:
 - a cyclone with a cylindroconical body, internal to said chamber, and comprising a tangential inlet tube for feeding said cyclone with a gas/liquid mixture, said tube being located in the upper part of said chamber,
 - an outlet tube for discharging a separated gas stream, said outlet tube located at the top of said cylindroconical body, said outlet tube opening outside of the chamber of the gas-liquid separator, and
 - an opening at the base of said cylindroconical body, said opening being connected to a dipleg for a liquid flow, said dipleg opening into said liquid guard zone at the bottom of the chamber of said gas-liquid separator; and/or
 - a gas-liquid separation device equipped with a helical spiral located in the upper part of said chamber, said gas-liquid separation device being capped by an upper cap which comprises at its upper end a gas discharge duct and at its lower end a vertical duct concentric with the intake duct allowing the separated liquid to return to the liquid guard zone at the bottom of the chamber of said gas-liquid separator;
 - optionally means for injecting an entraining agent and/or inert gas stream.

According to this particular embodiment, the lower part of the chamber, and more particularly the liquid guard zone at the bottom of the chamber, may be equipped with a stirrer. Still according to this particular embodiment, a pump, in particular a pump capable of entraining viscous fluids, also referred to as a melt pump, can be used at the external end (with respect to said gas-liquid separator) of said outlet pipe located in the bottom of the chamber.

According to a preferred embodiment, said purification means B) comprise at least solid-liquid separation means advantageously followed by an adsorption device. In this particular

embodiment, said solid-liquid separation means in particular comprise at least one decanter optionally followed by at least one other solid-liquid separation means, for example at least one filter.

Optionally, the solvent-polymer separation device C) may comprise an intermediate liquid-liquid or supercritical-liquid separation section, upstream of said gas-liquid separation section or of the first gas-liquid separation section of the series. In this particular embodiment, said liquid-liquid or supercritical-liquid separation section is connected to at least one of the purification means, and the feed means of said gas-liquid separation section or of the first gas-liquid separation section of the series is connected to said liquid-liquid or supercritical-liquid separation section, and not to at least one of the purification means. The optional intermediate supercritical-liquid separation section preferably comprises at least systems for adjusting the temperature and pressure, devices for the separation by density difference, for example decantation equipment, of two liquid phases of different density or of a liquid phase and a supercritical phase, and systems for withdrawing a liquid phase comprising the targeted thermoplastics and systems for withdrawing another liquid phase and a supercritical phase, essentially composed of solvent and in particular dissolution solvent.

Optionally, the gas-liquid separation section or the first intermediate gas-liquid separation section and/or any optional intermediate liquid-liquid or supercritical-liquid separation section may comprise a system for introducing a stream of inert gas.

The treatment device according to the invention may also optionally comprise at least one system for introducing an additive, for example an antioxidant. In particular, said at least one additive introduction system is included in the solvent-polymer separation device, and is preferably located upstream of said gas-liquid separation section or upstream of the last gas-liquid separation section of the series. Preferably, when said solvent-polymer separation device comprises said at least one additive introduction system and a plurality of gas-liquid separation sections, said at least one additive introduction system is located downstream of the first gas-liquid separation section.

Said device for treating a plastic feedstock also advantageously comprises equipment for transport between said means, devices and systems.

Such a treatment device very advantageously allows recycling of any type of plastic feedstock comprising thermoplastics, in particular polyolefins, and recovery of a stream of purified thermoplastics, in particular a stream of purified polyolefins which has a very low content of residual solvent (in particular dissolution solvent).

The examples and figures that follow illustrate the invention, in particular particular embodiments of the invention, without limiting the scope thereof.

LIST OF THE FIGURES

Figure 1 represents a particular embodiment of the process according to the invention. The particular embodiment of Figure 1 corresponds to the process described in Example 1.

- 5 Figure 2 represents a preferred embodiment of the process according to the invention. The embodiment of Figure 2 corresponds to the process described in Example 2.

Figure 3 represents a particular embodiment of the process according to the invention. The embodiment of Figure 3 corresponds to the process described in Example 3.

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EXAMPLES

In the examples below, the analyses performed on the feedstock and the products obtained are as follows:

- the volatile organic compound (VOC) content, which gives an indication of the solvent content, in particular the residual solvent content in the targeted thermoplastics stream, is determined by headspace (HS) gas chromatography coupled with mass spectrometry;
- the ash content, which gives an indication of the content of inorganic impurities, is determined by thermogravimetric analysis (or TGA). The ash content is determined by thermogravimetric analysis (or TGA) using a Perkin Elmer TGA 8000 apparatus, according to the standard ISO 11358-1 (2014). A sample of 10-20 mg of material is placed on a platinum plate. The temperature is equilibrated at 50°C for 10 minutes, then increases at a heating rate of 20°C/min to 950°C under a nitrogen stream. The ash content corresponds to the weight determined at 850°C relative to the weight of the starting sample, expressed as a weight percentage (% by weight);
- the colour parameters are expressed in the CIE L*a*b* reference system (defined by the Commission Internationale de l'Eclairage (CIE)), determined by colorimetry (according to the standard ISO 11664-4), with:
 - a lightness (or luminance) parameter L*, such that the closer L* is to 100, the clearer or more transparent the analysed solid; conversely, the closer L* is to 0, the more opaque the analysed solid;
 - a parameter a* (corresponding to a green-red axis), which measures the colour ranging from green (negative values) to red (positive values); a target value for a* is a value approaching 0;

- a parameter b^* (corresponding to a blue-yellow axis), which measures the colour ranging from blue (negative values) to yellow (positive values); a target value for b^* is a value approaching 0.

The $L^*a^*b^*$ values are determined using a Standard Konica/Minolta Colorimeter CM-3700A instrument, on solid samples of approximately 20 g of cryomilled material. They represent a first indicator of the purity of the polyolefin-based product.

Example 1 (in accordance with the invention)

The process of Example 1 is illustrated schematically in Figure 1.

Dissolution step a):

10 A feedstock 1 obtained from plastic waste and containing 95% by weight of polypropylene (PP) is introduced in flake form into an extruder heated to 200°C. At the extruder outlet, the feedstock is at least partly in molten form and is mixed with n-pentane 2 used as dissolution solvent and preheated to 200°C, in a solvent/feedstock weight ratio of 4/1. The mixture comprising the solvent and the feedstock is introduced into a stirred reactor and maintained
15 at 190°C and 2.0 MPa absolute for a residence time of 1 hour. A crude polymer solution 3 is then obtained.

Purification step b):

The crude polymer solution 3, which is continuously recovered from the stirred reactor, is injected into a decanter operated at 190°C and 2.0 MPa. The residence time in the decanter
20 is 1 hour, corresponding to the ratio between the working volume of the decanter (that is to say the volume of material in the decanter which is a function of the degree of filling of the decanter) and the volume flow rate of crude polymer solution 3 feeding the decanter.

Impurities are deposited at the bottom of the decanter, forming a “cake” which is purged discontinuously (stream 5). At the decanter outlet, the recovered polymer solution is filtered
25 through a filter with a 10 µm mesh aperture and then through a filter with a 1 µm mesh aperture.

The filtered polymer solution is then sent to an adsorption column containing a bed of activated carbon, and operated at 190°C and 2.0 MPa absolute (i.e. at an adsorption column outlet pressure of 2.0 MPa).

30 The adsorbed polymer solution 4, recovered at the outlet of the adsorption column, is then subjected to a solvent-polymer separation step.

Solvent-polymer separation step c):

The solvent-polymer separation step implements a gas-liquid separation section c1. An antioxidant 7, Irgafos® 168, is introduced into adsorbed polymer solution 4, so as to represent 600 ppm by weight of antioxidant relative to the weight of polypropylene included in the adsorbed polymer solution 4. The mixture then feeds the gas-liquid separation section c1 which is operated at an inlet temperature of 180°C and a pressure of 0.14 MPa absolute.

At the outlet of the gas-liquid separation section c1, a gaseous effluent g1 and a liquid effluent l1 are recovered. The gaseous effluent g1 can then be completely or partly purged and/or recycled. The liquid effluent l1 is placed under atmospheric conditions, i.e. at a temperature of about 20°C and a pressure of about 0.1 MPa.

A solid A (stream 6) is obtained. It is analysed by the methods described above. The results are presented in Table 1.

Table 1

	Feedstock	Solid A
VOC content	— ⁽¹⁾	5% by weight
Ash content	1.1% by weight	< 1000 ppm by weight
Colorimetry:		
Cielab – L	57.5	92.8
Cielab – a	14.7	0.2
Cielab - b	10.8	4.6

⁽¹⁾: the VOC content of the feedstock was not measured.

Solid A is composed of polypropylene, purified since it has a reduced ash content (<1000 ppm by weight) (and despite the introduction of antioxidant in step c)) compared to that of the feedstock (1.1% by weight) and Cielab colorimetry parameters that are also improved compared to those of the feedstock. Moreover, the solid A shows a VOC content, and therefore a residual solvent content that is satisfactory (5% by weight of volatile organic compounds VOC relative to the weight of solid A).

Example 2 (in accordance with the invention)

The process detailed in Example 2 is illustrated schematically in Figure 2.

A feedstock 1 identical to that of Example 1, that is to say derived from plastic waste and containing 95% by weight of polypropylene (PP), is treated in Example 2. The process of

Example 2 comprises the same dissolution steps a) and purification steps b) as those described in Example 1.

Solvent-polymer separation step c):

The adsorbed polymer solution 4 recovered at the adsorption column outlet is then subjected to a solvent-polymer separation step c), using four successive gas-liquid separation sections (or stages) c1, c2, c3, c4. The gas-liquid separation sections (or stages) 1 to 4 (i.e. c1, c2, c3, c4) are operated under the following temperature conditions (the temperatures given below being the inlet temperatures for each section) and pressure conditions (the pressures being absolute pressures in each section):

Stage c1: $T = 180^{\circ}\text{C}$, $P = 0.79 \text{ MPa}$,

Stage c2: $T = 180^{\circ}\text{C}$, $P = 0.61 \text{ MPa}$,

Stage c3: $T = 180^{\circ}\text{C}$, $P = 0.14 \text{ MPa}$,

Stage c4: $T = 250^{\circ}\text{C}$, $P = 0.0014 \text{ MPa}$ (i.e. 1.4 kPa or 14 mbar).

The absorbed polymer solution 4, recovered at the outlet of the adsorption column, feeds the first gas-liquid separation section c1. The liquid effluent I1 produced by the first gas-liquid separation section c1 feeds the second section c2. The liquid effluent I2 produced by the second gas-liquid separation section c2 feeds the third section c3. An antioxidant 7, Irgafos® 168, is introduced into the liquid effluent I3 produced by the third gas-liquid separation section c3, so as to represent 600 ppm by weight of antioxidant relative to the weight of polypropylene included in the liquid effluent I3, and the mixture then feeds the fourth gas-liquid separation section c4. At the outlet of the fourth gas-liquid separation section c4, a liquid effluent I4 is recovered and placed under atmospheric conditions, i.e. at a temperature of about 20°C and a pressure of about 0.1 MPa.

A solid B (stream 6) is then obtained. It is analysed by the methods described above. The results are presented in Table 2.

Each gas-liquid separation section c1, c2, c3, c4 also produces a gaseous effluent, respectively streams g1, g2, g3 and g4. The gaseous effluents g1, g2, g3 and g4 produced are recovered and can then be completely or partially purged and/or recycled.

Table 2

	Feedstock	Solid B
VOC content	_(1)	500 ppm by weight
Ash content	1.1% by weight	< 1000 ppm by weight

Colorimetry:		
Cielab – L	57.5	92.9
Cielab – a	14.7	-0.3
Cielab – b	10.8	4.6

⁽¹⁾: the VOC content of the feedstock was not measured.

Solid B is composed of polypropylene, purified since it has a reduced ash content (<1000 ppm by weight) (and despite the introduction of antioxidant in step c)) compared to that of the feedstock (1.1% by weight) and Cielab colorimetry parameters that are also improved compared to those of the feedstock. Moreover, the solid B displays a VOC content, and therefore a residual solvent content that is very low (200 ppm by weight of volatile organic compounds VOC relative to the weight of solid B).

Example 3 (in accordance with the invention)

The process of Example 3 is illustrated schematically in Figure 3.

10 Dissolution step a):

A feedstock 1 obtained from plastic waste and containing 95% by weight of polypropylene (PP) is introduced in flake form into an extruder heated to 200°C. At the extruder outlet, the feedstock is at least partly in molten form and is mixed with n-pentane 2 used as dissolution solvent and preheated to 190°C, in a solvent/feedstock weight ratio of 4/1. The mixture comprising the solvent and the feedstock is introduced into a stirred reactor at 190°C and maintained at 190°C and 10.0 MPa absolute for a residence time of 1 hour. A crude polymer solution 3 is then obtained.

Purification step b):

The crude polymer solution 3, which is continuously recovered from the stirred reactor, is injected into a decanter operated at 190°C and 9.9 MPa. The residence time in the decanter is 1 hour, corresponding to the ratio between the working volume of the decanter (that is to say the volume of material in the decanter which is a function of the degree of filling of the decanter) and the volume flow rate of crude polymer solution 3 feeding the decanter.

Impurities are deposited at the bottom of the decanter, forming a “cake” which is purged discontinuously (stream 5). At the decanter outlet, the recovered polymer solution is filtered through a filter with a 10 µm mesh aperture and then through a filter with a 1 µm mesh aperture.

The filtered polymer solution is then sent to an adsorption column containing a bed of activated carbon, and operated at 190°C and 9.7 MPa absolute (i.e. at an adsorption column outlet pressure of 9.7 MPa).

The adsorbed polymer solution 4, recovered at the outlet of the adsorption column, is then subjected to a solvent-polymer separation step.

Solvent-polymer separation step c):

The solvent-polymer separation step uses a section c1 for separation of the solvent by supercritical decantation. An antioxidant 7, Irgafos® 168, is introduced into adsorbed polymer solution 4, so as to represent 600 ppm by weight of antioxidant relative to the weight of polypropylene included in the adsorbed polymer solution 4. The mixture then feeds the section c1 for separation of the solvent by supercritical decantation, which is operated at an inlet temperature of 209°C and a pressure of 4.1 MPa absolute.

At the outlet of the gas-liquid separation section c1, a supercritical effluent sc1 and a liquid effluent l1 are recovered. The supercritical effluent sc1 can then be completely or partially purged and/or recycled. The liquid effluent l1 is then subjected to a gas-liquid separation section (or stage) c2 at 180°C and 1 MPa. The gaseous effluent g1 produced is recovered and can then be completely or partly purged and/or recycled.

At the outlet of the gas-liquid separation section c2, a liquid effluent l2 is recovered and placed under atmospheric conditions, i.e. at a temperature of about 20°C and a pressure of about 0.1 MPa.

A solid C (stream 6) is then obtained. It is analysed by the methods described above. The results are presented in Table 3.

Table 3

	Feedstock	Solid C
VOC content	-(¹)	200 ppm by weight
Ash content	1.1% by weight	< 1000 ppm by weight
Colorimetry:		
Cielab – L	57.5	92.7
Cielab – a	14.7	0.1
Cielab - b	10.8	4.5

(¹): the VOC content of the feedstock was not measured.

Solid C is composed of polypropylene, purified since it has a reduced ash content (<1000 ppm by weight) (despite the introduction of antioxidant in step c)) compared to that of the feedstock (1.1% by weight) and Cielab colorimetry parameters that are also improved compared to those of the feedstock. Solid C displays a VOC content, and therefore a residual solvent content that is very low (200 ppm by weight of volatile organic compounds VOC relative to the weight of solid C).

CLAIMS

1. Process for treating a plastic feedstock (1) comprising thermoplastics, said process comprising:

a) a step of dissolving the plastic feedstock in a dissolution solvent (2), step a) being performed at a dissolution temperature of between 100°C and 300°C and at a dissolution pressure of between 0.1 and 100.0 MPa absolute, to obtain at least one crude polymer solution (3);

b) a step of purifying the crude polymer solution to obtain a purified polymer solution (4), comprising:

b1) a sub-step of separating out the insoluble matter; and/or

b2) a sub-step of washing, by contact with a dense solution; and/or

b3) a sub-step of extraction, by contact with an extraction solvent; and/or

b4) a sub-step of adsorption of the impurities by contact with an adsorbent; and then

c) a step of solvent-polymer separation of the purified polymer solution, to obtain a stream of purified thermoplastic polymers (6) and at least one solvent stream,

wherein said solvent-polymer separation step c) implements a gas-liquid separation section (c1) or a plurality of gas-liquid separation sections (c1, c2, c3, c4) operating in series,

wherein said gas-liquid separation section (c1) or each of the gas-liquid separation sections (c1, c2, c3, c4) is operated at an inlet temperature of between 100°C and 300°C, and at a pressure lower than the pressure at the outlet of step b),

wherein, when step c) implements a plurality of gas-liquid separation sections (c1, c2, c3, c4), the pressure of the subsequent section is lower than that of the preceding section,

wherein the purified polymer solution, obtained from the purification step b), feeds into said gas-liquid separation section (c1) or the first gas-liquid separation section (c1) of the series,

said gas-liquid separation section (c1) or each of the gas-liquid separation sections (c1, c2, c3, c4) producing a gaseous effluent (g1, g2, g3, g4), which corresponds to said at least one solvent stream, and a liquid effluent (l1, l2, l3, l4),

wherein, when step c) implements a plurality of gas-liquid separation sections (c1, c2, c3, c4), the liquid effluent from the preceding section feeds into the subsequent section,

the liquid effluent obtained from said gas-liquid separation section (c1) or from the last gas-liquid separation section in the series (c4) constituting said stream of purified thermoplastic polymers (6).

2. Process according to Claim 1, in which the dissolution solvent (2) and the plastic feedstock (1) feed into step a) in a weight ratio between the dissolution solvent and the plastic feedstock of between 0.2 and 100.0, preferably between 0.3 and 20.0, preferably between 1.0 and 10.0, even more preferentially between 3.0 and 7.0.
- 5 3. Process according to Claim 1 or 2, in which the dissolution solvent comprises at least one hydrocarbon-based compound, said dissolution solvent having a boiling point of between -50°C and 250°C, preferably between -15°C and 200°C, preferentially between 15°C and 160°C and preferably between 50°C and 120°C.
- 10 4. Process according to any one of the preceding claims, in which the dissolution solvent comprises an isomer or a mixture of isomers of butane, pentane, hexane, heptane, octane, nonane and/or decane, and preferably an isomer or a mixture of isomers of hexane, heptane and/or octane.
- 15 5. Process according to any one of the preceding claims, in which the pressure in the gas-liquid separation section (c1) or each of the gas-liquid separation sections (c1, c2, c3, c4) is greater than or equal to 0.000005 MPa absolute, in particular greater than or equal to 0.00001 MPa absolute, in particular greater than or equal to 0.0001 MPa absolute, more particularly greater than or equal to 0.0005 MPa.
- 20 6. Process according to any one of the preceding claims, in which said solvent-polymer separation step c) implements several successive gas-liquid separation sections, preferably at least two, preferentially between two and ten, very preferentially between two and five, for example three or four, successive gas-liquid separation sections.
- 25 7. Process according to Claim 6, in which the first gas-liquid separation section is operated at an inlet temperature of between 100°C and 300°C, preferably between 110°C and 275°C, and at a pressure of less than 100.0 MPa absolute, preferably less than 25.0 MPa absolute, preferentially less than 15.0 MPa absolute, and advantageously greater than or equal to 0.0008 MPa absolute;
the last section is operated at an inlet temperature of between 100°C and 300°C, preferably between 110°C and 275°C, and at a pressure of between 0.000005 and 1.00 MPa absolute, preferably between 0.00001 and 1.00 MPa absolute, preferentially between 0.0001 and 1.00
30 MPa absolute, very preferentially between 0.0005 and 0.10 MPa absolute, very preferably between 0.0005 and 0.0020 MPa absolute; and
the pressure in each intermediate section is adjusted in a decreasing manner between the pressure in the first section and the pressure in the last section.

8. Process according to any one of the preceding claims, in which the or each gaseous effluent produced is, totally or partly, purged and/or purified and/or fractionated and/or recycled to step a) and/or optionally step b).

5 9. Process according to any one of the preceding claims, in which step c) comprises an intermediate liquid-liquid or supercritical-liquid separation section, located upstream of the gas-liquid separation section or of the series of gas-liquid separation sections, to obtain a liquid phase, which comprises the targeted thermoplastics, and a second liquid phase or a supercritical phase which comprises dissolution solvent,
 10 and in which the liquid phase, which comprises the targeted thermoplastics, feeds into the gas-liquid separation section or the first gas-liquid separation section, in place of the purified polymer solution.

10. Process according to any one of the preceding claims, in which step c) comprises the introduction of at least one additive, in particular an antioxidant.

11. Process according to any one of the preceding claims, in which the purification step b) 15 comprises a sub-step b1) of separating out the insoluble matter, advantageously followed by an adsorption sub-step b4).

12. Process according to any one of the preceding claims, in which the plastic feedstock comprises polyolefins.

13. Device for treating a plastic feedstock to obtain a stream of purified thermoplastic 20 polymers, said device comprising:

- dissolution means for bringing into contact and at least partially dissolving the plastic feedstock in a dissolution solvent, and obtaining a crude polymer solution;

- purification means for purifying the crude polymer solution and obtaining a purified polymer solution;

25 - a solvent-polymer separation device, located downstream of said purification means, for separating the purified polymer solution into a stream of purified thermoplastic polymers and at least one solvent effluent,

characterized in that said solvent-polymer separation device comprises:

30 a gas-liquid separation section or a plurality of gas-liquid separation sections operating in series, preferably at least two, preferentially between two and five, for example three or four, successive gas-liquid separation sections,

at least one system for controlling the pressure in said gas-liquid separation section or in each gas-liquid separation section of the series, so as to adjust the pressure in said gas-liquid separation section or in each gas-liquid separation section of the series to a value lower than the operating pressure at the outlet of the purification means, and when said solvent-polymer separation device comprises a plurality of gas-liquid separation sections, so as to adjust the pressure in the subsequent section to a value lower than that in the preceding section,

said gas-liquid separation section or each gas-liquid separation section of the series comprising a feed system, a liquid withdrawal system and a gas withdrawal system,

wherein the feed system of said gas-liquid separation section or of the first gas-liquid separation section of the series is connected to at least one of the purification means and allows purified polymer solution to be fed to said solvent-polymer separation device,

wherein, when said solvent-polymer separation device comprises a plurality of gas-liquid separation sections, the feed system of the subsequent section is connected to the liquid withdrawal system of the preceding section,

wherein the liquid withdrawal system of said gas-liquid separation section or of the last gas-liquid separation section of the series makes it possible to recover said stream of purified thermoplastic polymers,

wherein the gas withdrawal system of said gas-liquid separation section or of each gas-liquid separation section of the series makes it possible to recover said at least one solvent effluent to be recovered, said at least one solvent effluent comprising dissolution solvent.

14. Device according to Claim 13, comprising an intermediate liquid-liquid or supercritical-liquid separation section, upstream of said gas-liquid separation section or of the first gas-liquid separation section of the series.

15. Device according to Claim 13 or 14, comprising an additive introduction system.