(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 036 191 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
03.08.2022 Bulletin 2022/31

(21) Application number: 21153966.3

(22) Date of filing: 28.01.2021

(51) International Patent Classification (IPC):
C10G 1/00 (2006.01) *C10G 1/10* (2006.01)
C10G 21/00 (2006.01) *C10G 21/02* (2006.01)
C10G 55/04 (2006.01)

(52) Cooperative Patent Classification (CPC):
C10G 1/10; C10G 1/002; C10G 21/00; C10G 21/02; C10G 55/04

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(71) Applicant: **Shell Internationale Research Maatschappij B.V.**
2596 HR The Hague (NL)

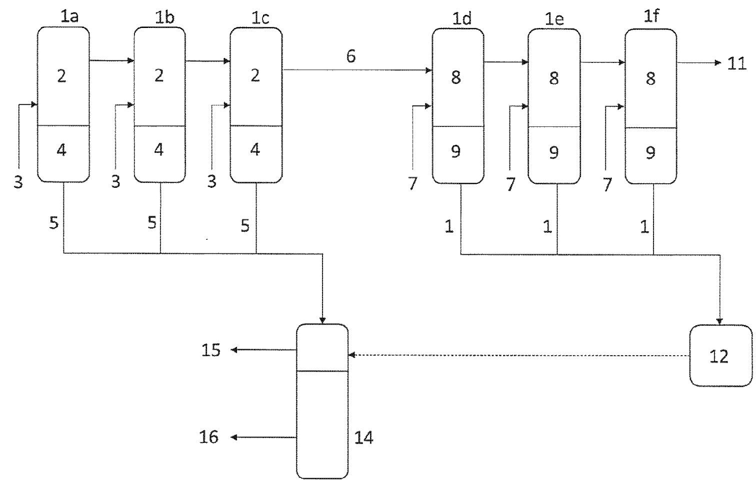
(72) Inventors:
- **LANGE, Jean Paul Andre Marie Joseph Ghislain**
  1031 HW Amsterdam (NL)
- **VAN ROSSUM, Guus**
  1031 HW Amsterdam (NL)
- **OLTHOF, Timothè Johannes**
  1031 HW Amsterdam (NL)
- **FISCHER, Kai Jürgen**
  1031 HW Amsterdam (NL)
- **STICHTER, Hendrik**
  1031 HW Amsterdam (NL)

(74) Representative: **Shell Legal Services IP**
PO Box 384
2501 CJ The Hague (NL)

(54) PROCESS FOR REMOVING CONTAMINANTS FROM RECYCLED OR RENEWABLE ORGANIC MATERIAL

(57) The present invention provides a process for the removal of contaminants from contaminated recycled or renewable organic material, comprising the steps of: i) providing a first solvent to a vessel containing the recycled or renewable organic material; ii) mixing the recycled or renewable organic material and the first solvent and then allowing a solvent phase, comprising at least a portion of the first solvent and at least a portion of the contaminants, and an oil phase, comprising at least a portion of the recycled or renewable organic material, to form; iii) removing at least a portion of the solvent phase from the vessel and retaining at least a portion of the oil phase in the vessel; and iv) optionally repeating steps i) to iii) one or more times.

Figure 1



EP 4 036 191 A1

Description

Field of the invention

[0001] The present invention is directed to a process for removing contaminants from recycled or renewable organic material, such as plastics pyrolysis oil; to a process for the recovery of aliphatic hydrocarbons from plastics comprising the above-mentioned process; and to a process for steam cracking a hydrocarbon feed comprising aliphatic hydrocarbons as recovered in one of the above-mentioned processes.

Background of the invention

[0002] Waste plastics can be converted via cracking of the plastics, for example by pyrolysis, to high-value chemicals, including olefins and aromatic hydrocarbons. Pyrolysis of plastics can yield product streams containing hydrocarbons in a wide boiling range. Hydrocarbons from such pyrolysis product streams can be further cracked in a steam cracker to produce high-value chemicals, including ethylene and propylene which are monomers that can be used in making new plastics.

[0003] WO2020212315 discloses a process for the recovery of aliphatic hydrocarbons from a liquid hydrocarbon feedstock stream comprising aliphatic hydrocarbons and additionally comprising aromatic hydrocarbons and/or polar components, said process comprising feeding the feedstock stream and an extraction solvent stream to a column; contacting the feedstock stream with the extraction solvent stream; and recovering aliphatic hydrocarbons by liquid-liquid extraction of aromatic hydrocarbons and/or polar components with the extraction solvent.

[0004] According to above-mentioned WO2020212315, said liquid hydrocarbon feedstock stream may comprise a liquid product produced by the pyrolysis of plastic waste. Further, according to WO2020212315, said extraction solvent may be selected from the group consisting of diols and triols, including monoethylene glycol, monopropylene glycol and any isomer of butanediol; glycol ethers, including oligoethylene glycols, including diethylene glycol and tetraethylene glycol, and ethers thereof, including diethylene glycol dimethylether; amides, including N-alkylpyrrolidone, including N-methylpyrrolidone, and dialkyl formamide, including dimethyl formamide; dialkylsulfoxide, including dimethylsulfoxide; sulfolane; N-formyl morpholine (NFM); and furan ring containing components, including furfural, 2-methyl-furan and furfuryl alcohol.

[0005] Recycled or renewable organic material, such as plastics pyrolysis oil, may contain contaminants that may need to be removed before it is further processed in a downstream process (e.g. in a steam cracker). For example, heteroatom containing organic contaminants have a negative impact on the yield, selectivity and reliability of steam crackers. Generally, there are certain specifications (maximum concentrations) for a number of heteroatom containing organic contaminants, especially chloride, nitrogen and/or oxygen containing contaminants, that a hydrocarbon feed should meet before it may be fed into a steam cracker.

[0006] It would be highly desirable to provide a simplified process for removing chemical contaminants, particularly organic chlorides, from recycled or renewable organic material, such as plastics pyrolysis oil, before it is further processed, such as in a steam cracker. It would be even more preferable if such a process could be carried out without the addition of complicated apparatus and infrastructure, and preferably on the same site where a further downstream process (e.g. steam cracking) is carried out. It is an object of the present invention to provide such process for removing contaminants from recycled or renewable organic material, such as plastics pyrolysis oil, which process is technically advantageous, efficient and affordable, in particular a process which does not have one or more of the above-mentioned disadvantages, as discussed above. Such technically advantageous process would preferably result in a relatively low energy demand and/or relatively low capital expenditure.

Summary of the invention

[0007] The present invention provides a process for the removal of contaminants from contaminated recycled or renewable organic material, comprising the steps of:

i) providing a first solvent to a vessel containing the recycled or renewable organic material;
ii) mixing the recycled or renewable organic material and the first solvent and then allowing a solvent phase, comprising at least a portion of the first solvent and at least a portion of the contaminants, and an oil phase, comprising at least a portion of the recycled or renewable organic material, to form;
iii) removing at least a portion of the solvent phase from the vessel and retaining at least a portion of the oil phase in the vessel; and
iv) optionally repeating steps i) to iii) one or more times.

[0008] Further, the present invention relates to a process for the recovery of aliphatic hydrocarbons from plastics, wherein at least part of the plastics comprises heteroatom containing organic compounds, said process comprising the steps of:

(I) cracking the plastics and recovering a hydrocarbon product comprising aliphatic hydrocarbons, heteroatom containing organic compounds and optionally aromatic hydrocarbons; and
(II) subjecting a liquid hydrocarbon feedstock, which comprises at least part of the hydrocarbon product obtained in step (I), to the above-mentioned process for the removal of contaminants from contaminated recycled or renewable organic material in a vessel.

[0009] Still further, the present invention relates to a process for steam cracking a hydrocarbon feed, wherein the hydrocarbon feed comprises aliphatic hydrocarbons as recovered in one of the above-mentioned processes.

Brief description of the drawings

[0010]

Figure 1 shows a graphical representation of the process of the present invention.
Figure 2 shows an exemplary embodiment of a vessel (1) to be used in the process of the present invention.

Detailed description of the invention

[0011] Each of the processes of the present invention comprises multiple steps. In addition, said process may comprise one or more intermediate steps between consecutive steps. Further, said process may comprise one or more additional steps preceding the first step and/or following the last step. For example, in a case where said process comprises steps a), b) and c), said process may comprise one or more intermediate steps between steps a) and b) and between steps b) and c). Further, said process may comprise one or more additional steps preceding step a) and/or following step c).
[0012] While the process(es) of the present invention and stream(s) and composition(s) used in said process(es) are described in terms of "comprising", "containing" or "including" one or more various described steps and components, respectively, they can also "consist essentially of" or "consist of" said one or more various described steps and components, respectively.".
[0013] In the context of the present invention, in a case where a stream or composition comprises two or more components, these components are to be selected in an overall amount not to exceed 100%.
[0014] Further, where upper and lower limits are quoted for a property then a range of values defined by a combination of any of the upper limits with any of the lower limits is also implied.
[0015] Unless indicated otherwise, where in the present specification reference is made to a boiling point this means the boiling point at 760 mm Hg pressure.

Contaminated recycled or renewable organic material

[0016] The feed to the present process comprises contaminated recycled or renewable organic material, i.e. recycled or renewable organic material which comprises contaminants. That is to say, in step i) of the present process, the vessel to which the first solvent is provided, contains such contaminated recycled or renewable organic material.
[0017] Within the present specification, the term "recycled or renewable organic material" refers to organic material which may be obtained 1) from a material that is recovered from a waste for reuse (i.e. recycled organic material) or 2) from a resource which may be replenished to overcome depletion of that resource caused by its usage (i.e. renewable organic material). The latter replenishable (renewable) resource may be a natural resource or a non-natural resource (e.g. including genetically engineered organisms). The recycled or renewable organic material may be in an unprocessed (i.e. raw) form (e.g. animal fat) or a processed form (e.g. used cooking oil). Within the present specification, the term "recycled or renewable organic material" does not refer to crude oil (fossil oil) which has not yet been subjected to refining.
[0018] In addition to the recycled or renewable organic material, in step i) of the present process, the vessel may also contain crude oil (fossil oil). Said crude oil is also referred to as petroleum, which is a naturally occurring liquid found in geological formations found beneath the Earth's surface. Such crude oil may be any crude oil which has not yet been subjected to refining. For example, said crude oil may be stabilized crude oil, i.e. crude oil that has been treated in a separator or collective stages of separators and stabilizers to remove gas and water. Further, in step i) of the present process, the vessel may also contain oil originating from refining crude oil.
[0019] In the present invention, the recycled or renewable organic material may comprise fats and/or oils of plant, microbial, algal and/or animal origin. Further, it may comprise waste-based oils and/or waste oils. Still further, it may

comprise material from any waste stream originating from processing said oils and/or fats.

[0020] Thus, in particular, in the present invention the recycled or renewable organic material may comprise one or more materials selected from the group consisting of plant based fats and oils, animal based fats and oils, waste-based oils, waste oils, algal oils and microbial oils. Preferably, the recycled or renewable organic material comprises a waste-based oil.

[0021] The above-mentioned term "plant based fats and oils" refers to fats and/or oils of plant origin, e.g. oils that can originate directly from plants or can be byproducts from various industrial sectors, such as agriculture or forest industry. Examples of plant based fats and oils include sludge palm oil, rapeseed oil, canola oil, colza oil, sunflower oil, soybean oil, hemp oil, olive oil, linseed oil, cottonseed oil, mustard oil, palm oil, arachis oil, castor oil and coconut oil. Other examples of plant based fats and oils include fats and oils produced from biomass, in particular from lignocellulosic biomass, by various liquefying methods, such as hydrothermal liquefaction, or by pyrolysis.

[0022] The term "animal based fats and oils" refers to fats and/or oils of animal origin, i.e lipid materials derived from animals. Examples of animal based fats and oils include suet, tallow, blubber, lard, train oil, milk fat, fish oil, poultry oil and poultry fat. The term "microbial oils" refers to triglycerides (lipids) produced by microbes. The term "algal oils" refers to oils derived directly from algae.

[0023] The term "waste-based oils" refers to oils produced from waste streams, such as waste plastics and end-of-life-tires. Examples of waste-based oils include waste plastics pyrolysis oil and end-of-life-tire pyrolysis oil. The waste-based oil may be an oil based on fossil waste or non-fossil waste. An example of a non-fossil waste is waste plastics synthesized from biomass, for example polyethylene synthesized from bio-ethanol through dehydration of the ethanol and subsequent polymerization of the ethylene thus formed. More preferably, the recycled or renewable organic material comprises plastics pyrolysis oil, in particular waste plastics pyrolysis oil.

[0024] The term "waste oils" refers to any oils that, through contamination, have become unsuitable for their original purpose. Examples of waste oils include used lubricant oils, hydraulic oils, transformer oils and oils used in metal working.

[0025] In the present invention, the recycled or renewable organic material comprises contaminants. Within the present specification, the term "contaminants" refers to one or more components which need to be removed from the recycled or renewable organic material, wherein the total amount of said one or more components to be removed is less than 50 wt.%, based on the total amount of the recycled or renewable organic material. Said amount of contaminants present in the contaminated recycled or renewable organic material before the process of the present invention is greater than 0 wt.% and may be at least 0.5 wt.% or at least 1 wt.% or at least 3 wt.% or at least 5 wt.% or at least 10 wt.% or at least 15 wt.% or at least 20 wt.%, and is less than 50 wt.% and may be at most 30 wt.% or at most 20 wt.% or at most 10 wt.% or at most 5 wt.%.

[0026] Within the present specification, the term "contaminants" refers to components which are present in the contaminated recycled or renewable organic material before the process of the present invention, and may also refer to components which are not present therein before the process of the present invention but which are introduced therein when performing the process of the present invention, such as the first solvent a portion of which may end up in the oil phase from step ii) and/or the below-mentioned second solvent a portion of which may end up in the oil phase from below-mentioned optional step vi).

[0027] In the present invention, the contaminated recycled or renewable organic material may comprise aliphatic hydrocarbons, heteroatom containing organic compounds and optionally aromatic hydrocarbons. Preferably, in the present invention, said heteroatom containing organic compounds are removed as contaminants from the recycled or renewable organic material. These may be removed as said heteroatom containing organic compounds and/or as heteroatom containing inorganic compounds including salts. Further, depending on the end use of the aliphatic hydrocarbons and the relative amount of aromatic hydrocarbons, said aromatic compounds may be removed as contaminants from the recycled or renewable organic material. For example, the pyrolysis of plastics may result in such contaminated organic material comprising aliphatic hydrocarbons, heteroatom containing organic compounds and optionally aromatic hydrocarbons. Other contaminants which may be removed from the contaminated recycled or renewable organic material, especially from plastics pyrolysis oil, may comprise salts, silicon containing compounds and/or metals.

[0028] Hereinbelow, components which may be present in the contaminated recycled or renewable organic material before the process of the present invention, are described in more detail.

[0029] Preferably, the recycled or renewable organic material comprises both aliphatic hydrocarbons having a boiling point of from 30 to 300 °C and aliphatic hydrocarbons having a boiling point of from greater than 300 to 600 °C in a weight ratio of from 99:1 to 1:99. The amount of aliphatic hydrocarbons having a boiling point of from 30 to 300 °C, based on the total amount of aliphatic hydrocarbons having a boiling point of from 30 to 600 °C, may be at most 99 wt.% or at most 80 wt.% or at most 60 wt.% or at most 40 wt.% or at most 30 wt.% or at most 20 wt.% or at most 10 wt.%. Further, the amount of aliphatic hydrocarbons having a boiling point of from 30 to 300 °C, based on the total amount of aliphatic hydrocarbons having a boiling point of from 30 to 600 °C, may be at least 1 wt.% or at least 5 wt.% or at least 10 wt.% or at least 20 wt.% or at least 30 wt.%.

[0030] Thus, advantageously, the recycled or renewable organic material may comprise varying amounts of aliphatic hydrocarbons within a wide boiling point range of from 30 to 600 °C. Accordingly, as with the boiling point, the carbon number of the aliphatic hydrocarbons in the recycled or renewable organic material may also vary within a wide range, for example of from 5 to 50 carbon atoms. The carbon number of the aliphatic hydrocarbons in the recycled or renewable organic material may be at least 4 or at least 5 or at least 6 and may be at most 50 or at most 40 or at most 30 or at most 20.

[0031] The amount of aliphatic hydrocarbons in the recycled or renewable organic material, based on the total weight of the recycled or renewable organic material, may be at least 30 wt.% or at least 50 wt.% or at least 80 wt.% or at least 90 wt.% or at least 95 wt.% or at least 99 wt.% and may be smaller than 100 wt.% or at most 99 wt.% or at most 90 wt.% or at most 80 wt.% or at most 70 wt.%. The aliphatic hydrocarbons may be cyclic, linear and branched.

[0032] The aliphatic hydrocarbons in the recycled or renewable organic material may comprise non-olefinic (paraffinic) and olefinic aliphatic compounds. The amount of paraffinic aliphatic compounds in the recycled or renewable organic material, based on the total weight of the recycled or renewable organic material, may be at least 20 wt.% or at least 40 wt.% or at least 60 wt.% or at least 80 wt.% and may be smaller than 100 wt.% or at most 99 wt.% or at most 80 wt.% or at most 60 wt.%. Further, the amount of olefinic aliphatic compounds in the recycled or renewable organic material, based on the total weight of the recycled or renewable organic material, may be smaller than 100 wt.% or at least 20 wt.% or at least 40 wt.% or at least 60 wt.% or at least 80 wt.% and may be at most 99 wt.% or at most 80 wt.% or at most 60 wt.%.

[0033] Further, the olefinic compounds may comprise aliphatic compounds having one carbon-carbon double bond (mono-olefins) and/or aliphatic compounds having two or more carbon-carbon double bonds which latter compounds may be conjugated or nonconjugated. That is to say, the two or more carbon-carbon double bonds may be conjugated or not conjugated. The aliphatic compounds having two or more carbon-carbon double bonds may include compounds having double bonds at alpha and omega positions. The amount of mono-olefins in the recycled or renewable organic material, based on the total weight of the recycled or renewable organic material, may be at least 20 wt.% or at least 40 wt.% or at least 60 wt.% or at least 80 wt.% and may be smaller than 100 wt.% or at most 99 wt.% or at most 80 wt.% or at most 60 wt.%. Further, the amount of conjugated aliphatic compounds having two or more carbon-carbon double bonds in the recycled or renewable organic material, based on the total weight of the recycled or renewable organic material, may be greater than 0 wt.% or at least 10 wt.% or at least 20 wt.% or at least 40 wt.% or at least 60 wt.% and may be at most 80 wt.% or at most 60 wt.% or at most 40 wt.%.

[0034] Within the present specification, an aliphatic hydrocarbon which contains one or more heteroatoms is a "heteroatom containing organic compound" as further described below. Unless indicated otherwise, either explicitly or by context, within the present specification, the term "aliphatic hydrocarbons" does not include heteroatom containing aliphatic hydrocarbons. Further, unless indicated otherwise, either explicitly or by context, within the present specification, the term "aliphatic hydrocarbons" does not include conjugated aliphatic compounds having two or more carbon-carbon double bonds.

[0035] In addition to the above-described aliphatic hydrocarbons, the recycled or renewable organic material may comprise heteroatom containing organic compounds and optionally aromatic hydrocarbons.

[0036] The amount of aromatic hydrocarbons in the recycled or renewable organic material, based on the total weight of the recycled or renewable organic material, may be 0 wt.% or greater than 0 wt.% or at least 5 wt.% or at least 10 wt.% or at least 15 wt.% or at least 20 wt.% or at least 25 wt.% or at least 30 wt.% and may be at most 50 wt.% or at most 40 wt.% or at most 30 wt.% or at most 20 wt.%. The aromatic hydrocarbons may comprise monocyclic and/or polycyclic aromatic hydrocarbons. An example of a monocyclic aromatic hydrocarbon is styrene. The polycyclic aromatic hydrocarbons may comprise non-fused and/or fused polycyclic aromatic hydrocarbons. An example of a non-fused polycyclic aromatic hydrocarbon is oligostyrene. Styrene and oligostyrene may originate from polystyrene. Examples of fused polycyclic aromatic hydrocarbons are naphthalene and anthracene, as well as alkyl naphthalene and alkyl anthracene. The aromatic ring or rings in the aromatic hydrocarbons may be substituted by one or more hydrocarbyl groups, including alkyl groups (saturated) and alkylene groups (unsaturated).

[0037] Within the present specification, an aromatic hydrocarbon which contains one or more heteroatoms is a "heteroatom containing organic compound" as further described below. Unless indicated otherwise, either explicitly or by context, within the present specification, the term "aromatic hydrocarbons" does not include heteroatom containing aromatic hydrocarbons.

[0038] Further, the amount of heteroatom containing organic compounds in the recycled or renewable organic material, based on the total weight of the recycled or renewable organic material, may be greater than 0 wt.% and may be at least 0.5 wt.% or at least 1 wt.% or at least 3 wt.% or at least 5 wt.% or at least 10 wt.% or at least 15 wt.% or at least 20 wt.% and may be at most 30 wt.% or at most 20 wt.% or at most 10 wt.% or at most 5 wt.%.

[0039] The heteroatom containing organic compounds in the recycled or renewable organic material contain one or more heteroatoms, which may be oxygen, nitrogen, sulfur and/or a halogen, such as chlorine, suitably oxygen, nitrogen and/or a halogen. The heteroatom containing organic compounds may comprise one or more of the following moieties: amine, imine, nitrile, alcohol, ether, ketone, aldehyde, ester, acid, amide, carbamate (occasionally named urethane) and urea.

[0040] Further, the above-mentioned heteroatom containing organic compounds may be aliphatic or aromatic. An example of an aliphatic, heteroatom containing organic compound is oligomeric polyvinyl chloride (PVC). Oligomeric PVC may originate from polyvinyl chloride. Aromatic, heteroatom containing organic compounds may comprise monocyclic and/or polycyclic aromatic, heteroatom containing organic compounds. Examples of monocyclic aromatic, heteroatom containing organic compounds are terephthalic acid and benzoic acid. An example of a polycyclic aromatic, heteroatom containing organic compound is oligomeric polyethylene terephthalate (PET). Terephthalic acid, benzoic acid and oligomeric PET may originate from polyethylene terephthalate. Examples of nitrogen containing organic compounds are compounds originating from polyurethane and polyamides including nylon.

[0041] Unless indicated otherwise, either explicitly or by context, within the present specification, the term "heteroatom containing organic compounds" means heteroatom containing organic compounds in or originating from the recycled or renewable organic material. Further, unless indicated otherwise, either explicitly or by context, within the present specification, the term "heteroatom containing organic compounds" does not include the extraction solvent and/or washing solvent as defined in the present specification.

[0042] Additionally, the recycled or renewable organic material may comprise salts. Said salts may comprise organic and/or inorganic salts. The salts may comprise ammonium, an alkali metal, an alkaline earth metal or a transition metal as the cation and a carboxylate, sulphate, phosphate or a halide as the anion.

[0043] Further, additionally, the recycled or renewable organic material may comprise silicon containing compounds, such as silica and siloxane compounds.

[0044] Still further, additionally, the recycled or renewable organic material may comprise metals.

[0045] Further, since in the present process heteroatom containing organic compounds and any other contaminants may easily be removed, the feed to the present process can advantageously tolerate a relatively high amount of such heteroatom containing organic compounds and other contaminants. Thus, waste plastic that may be pyrolyzed to produce a feed to the present process may comprise heteroatom-containing plastics, such as polyvinyl chloride (PVC), polyethylene terephthalate (PET) and polyurethane (PU). In specific, mixed waste plastic may be pyrolyzed that in addition to heteroatom-free plastics, such as polyethylene (PE) and polypropylene (PP), contains a relatively high amount of such heteroatom-containing plastics.

Batchwise removal of contaminants from recycled or renewable organic material

[0046] Surprisingly, many contaminants can be removed from contaminated recycled or renewable organic material using a simple process comprising carrying out the steps of i) mixing the recycled or renewable organic material with a first solvent in a vessel, then ii) allowing two separate phases to form in that same vessel and finally iii) removing the solvent-containing phase, which is preferably the lower phase (bottom phase), from that vessel. These steps are preferably then repeated a number of times with the same first solvent in the same vessel.

[0047] The process of the present invention may be carried out in any vessel in which two liquids may effectively be mixed. Advantageously, the process may be carried out in recycled or renewable organic material storage tanks as long as they are fitted with some means of mixing the contents, providing a simple solution to handling contaminated recycled or renewable organic material supplies. Mixing may be carried out by any suitable method that allows thorough contacting between the solvent and the recycled or renewable organic material. Said methods include allowing the solvent to flow through the recycled or renewable organic material under gravity; mixing involving an agitation device such as a stirrer, a jet or a pump; and recirculating the tank contents through external piping. One method of mixing the solvent and the recycled or renewable organic material is by pumping the solvent into the vessel containing said recycled or renewable organic material using a pump with enough force to allow mixing of the solvent and the recycled or renewable organic material. In a particularly preferred embodiment of the invention, mixing is carried out by recirculation, that is by removing a portion of the vessel contents at one point of the vessel and circulating it through external piping, preferably by using a pump, before returning it to the vessel at a different point.

[0048] The process of the present invention is particularly advantageous for the removal of organic halides, specifically organic chlorides, from recycled or renewable organic material. Therefore, it can be said that that preferably the contaminants to be removed from the recycled or renewable organic material comprise organic chlorides.

[0049] The total amount of organic chloride contaminants present in the contaminated recycled or renewable organic material before the process of the present invention may be greater than 0 ppmw or greater than 10 ppmw or at least 20 ppmw or at least 50 ppmw or at least 100 ppmw, and may be at most 5000 ppmw or at most 3000 ppmw, based on the overall weight of the recycled or renewable organic material.

[0050] In the process of the invention, a first solvent is provided to a vessel containing the contaminated recycled or renewable organic material; the recycled or renewable organic material and the first solvent are mixed; and then mixing is stopped allowing a solvent phase, comprising at least a portion of the first solvent and at least a portion of the contaminants, and an oil phase, comprising at least a portion of the recycled or renewable organic material, to form. At least a portion of this solvent phase is removed from the vessel leaving at least a portion of the oil phase in the vessel.

Preferably, these steps are then repeated one or more times with the same solvent in the same vessel.

[0051] The solvent may be provided directly to the vessel or may be provided indirectly, for example, in the embodiment wherein mixing is carried out by recirculation, by providing the solvent into the external piping through which a portion of the vessel contents are being circulated.

[0052] The weight ratio of the solvent to the recycled or renewable organic material in the vessel may be at least 0.05:1 or at least 0.2:1 or at least 0.5:1 or at least 1:1 or at least 2:1 or at least 3:1, and may be at most 5:1 or at most 3:1 or at most 2:1 or at most 1:1.

[0053] The temperature in the vessel may be at least 0 °C or at least 20 °C or at least 30 °C or at least 40 °C or at least 50 °C, and may be at most 400 °C or at most 350 °C or at most 300 °C or at most 250 °C or at most 200 °C or at most 150 °C or at most 100 °C or at most 70 °C or at most 60 °C or at most 50 °C or at most 40 °C.

[0054] The pressure in the vessel may be at least 100 mbara or at least 500 mbara or at least 1 bara or at least 1.5 bara or at least 2 bara, and may be at most 20 bara or at most 15 bara or at most 10 bara or at most 5 bara or at most 3 bara or at most 2 bara or at most 1.5 bara.

[0055] The temperature and pressure in the vessel are preferably such that all of the contents of the vessel remain in the liquid state.

[0056] Preferably, steps i) to iii) of the present process are repeated 2 or more times, i.e. steps i) to iii) are carried out 3 times or more in total. Even more preferably, steps i) to iii) of the present process are repeated 3 or more times, i.e. steps i) to iii) are carried out 4 times or more in total.

[0057] In each repeat of step i) a fresh solvent may be used. It is preferable that the same type of solvent is used in each repeat of steps i) to iii).

[0058] Optionally, after having performed above steps i), ii) and iii) one or more times using the first solvent, the following steps v) to viii) may be performed using another, second solvent:

v) providing a second solvent to the vessel containing the recycled or renewable organic material;
vi) mixing the recycled or renewable organic material and the second solvent and then allowing a solvent phase, which is preferably the lower phase (bottom phase), comprising at least a portion of the second solvent and at least a portion of the contaminants, and an oil phase, comprising at least a portion of the recycled or renewable organic material, to form;
vii) removing at least a portion of the solvent phase from the vessel and retaining at least a portion of the oil phase in the vessel; and
viii) optionally repeating steps v) to vii) one or more times.

[0059] In the above-mentioned optional embodiment, the second solvent is not identical to the first solvent used in steps i) to iv) of the present process.

[0060] Further, optionally, after having performed above steps v), vi) and vii) one or more times using a second solvent, the following steps ix) to xii) may be performed using another, third solvent:

ix) providing a third solvent to the vessel containing the recycled or renewable organic material;
x) mixing the recycled or renewable organic material and the third solvent and then allowing a solvent phase, which is preferably the lower phase (bottom phase), comprising at least a portion of the third solvent and at least a portion of the contaminants, and an oil phase, comprising at least a portion of the recycled or renewable organic material, to form;
xi) removing at least a portion of the solvent phase from the vessel and retaining at least a portion of the oil phase in the vessel; and
xii) optionally repeating steps ix) to xi) one or more times.

[0061] In the above-mentioned further optional embodiment, the third solvent is not identical to the second solvent used in above-mentioned steps v) to viii).

[0062] Optional steps v) to viii) and optional steps ix) to xii) may be carried out in the same way as steps i) to iv). Therefore, embodiments and preferences as described above for steps i) to iv), including for example weight ratio of solvent to recycled or renewable organic material in the vessel and temperature and pressure in the vessel, also apply to optional steps v) to viii) and optional steps ix) to xii).

[0063] Further, it is preferred that the solvent(s) that is or may be used in the present process, that is to say the first solvent and the optional second and third solvents, contain(s) one or more heteroatoms, which may be oxygen, nitrogen and/or sulfur. Still further, it is preferred that said solvent(s) is (are) thermally stable at the selected temperature. Still further, said solvent(s) may have a boiling point which is at least 50 °C or at least 80 °C or at least 100 °C or at least 120 °C and at most 300 °C or at most 200 °C or at most 150 °C. Still further, it is preferred that said solvent(s) has (have) a density which is at least 3% or at least 5% or at least 8% or at least 10% or at least 15% or at least 20% and at most

50% or at most 40% or at most 35% or at most 30% higher than the density of the contaminated recycled or renewable organic material. Still further, it is preferred that said solvent(s) has (have) no or a relatively low miscibility in heptane. Preferably, said solvent(s) has (have) such miscibility in heptane that at most 30 wt.% or at most 20 wt.% or at most 10 wt.% or at most 3 wt.% or at most 1 wt.% or at most 0.5 wt.% or at most 0.1 wt.% of solvent, based on weight of heptane, is miscible in heptane. The miscibility of a certain compound in another compound, such as heptane, may be determined by any general method known to a skilled person in the art, including ASTM method D1476. Where in the present specification reference is made to the miscibility of a compound in another compound, this means miscibility at 25 °C.

[0064] In the present invention, the first solvent may be washing solvent a) or extraction solvent b) as described below.

[0065] Further, the optional second solvent may be extraction solvent b) or washing solvent c) as described below. In a case wherein the first solvent is washing solvent a), the second solvent may be extraction solvent b). And in a case wherein the first solvent is extraction solvent b), the second solvent may be washing solvent c).

[0066] Still further, the optional third solvent may be washing solvent c) as described below. In a case wherein the first solvent is washing solvent a) and the second solvent is extraction solvent b), said third solvent may be washing solvent c).

[0067] It is preferred that the miscibilities of washing solvents a) and c) in heptane are lower than the miscibility of extraction solvent b) in heptane, as further described below.

[0068] Washing solvent a) may have a Hansen solubility parameter distance $R_{a,heptane}$ with respect to heptane as determined at 25 °C of at least 10 $MPa^{1/2}$, preferably at least 20 $MPa^{1/2}$, more preferably at least 30 $MPa^{1/2}$, more preferably at least 40 $MPa^{1/2}$. Further, said $R_{a,heptane}$ for washing solvent a) may be at most 55 $MPa^{1/2}$, more preferably at most 50 $MPa^{1/2}$, more preferably at most 45 $MPa^{1/2}$. For example, said $R_{a,heptane}$ for water is 45 $MPa^{1/2}$. Hansen solubility parameters are further described hereinbelow in relation to extraction solvent b).

[0069] Further, washing solvent a) may have a solubility of sodium chloride, in g of NaCl per 100 g of solvent as determined at 25 °C, of at least 0.1 g/100 g, preferably at least 0.3 g/100 g, more preferably at least 0.5 g/100 g, more preferably at least 0.7 g/100 g, more preferably at least 1 g/100 g, more preferably at least 2 g/100 g, more preferably at least 3 g/100 g, more preferably at least 4 g/100 g and most preferably at least 5 g/100 g, and may be at most 50 g/100 g or at most 40 g/100 g or at most 36 g/100 g. For example, said solubility of sodium chloride for water is 36 g/100 g.

[0070] Still further, washing solvent a) may comprise one or more solvents selected from the group consisting of water, ammonia and organic solvents having a Hansen solubility parameter distance $R_{a,DEAA}$ with respect to diethylammonium acetate (DEAA) as determined at 25 °C of at most 15 $MPa^{1/2}$, preferably at most 13 $MPa^{1/2}$, more preferably at most 11 $MPa^{1/2}$. Further, said $R_{a,DEAA}$ for washing solvent a) may be at least 5 $MPa^{1/2}$, preferably at least 8 $MPa^{1/2}$, more preferably at least 10 $MPa^{1/2}$. For example, said $R_{a,DEAA}$ for monoethylene glycol (MEG) is 12 $MPa^{1/2}$. Further, preferably, said organic solvents for washing solvent a) have a $R_{a,heptane}$ which is greater than the $R_{a,DEAA}$ for the same solvent, wherein said difference in $R_{a,heptane}$ and $R_{a,DEAA}$ is at least 15 $MPa^{1/2}$, more preferably at least 16 $MPa^{1/2}$, most preferably at least 17 $MPa^{1/2}$. Further, preferably, said difference in $R_{a,heptane}$ and $R_{a,DEAA}$ is at most 25 $MPa^{1/2}$, more preferably at most 22 $MPa^{1/2}$, most preferably at most 20 $MPa^{1/2}$. For example, said difference in $R_{a,heptane}$ and $R_{a,DEAA}$ for monoethylene glycol is 16.3 $MPa^{1/2}$.

[0071] In specific, washing solvent a) may comprise one or more solvents selected from the group consisting of water, ammonia and organic solvents selected from the group consisting of diols and triols, including monoethylene glycol (MEG), monopropylene glycol (MPG) and glycerol; glycol ethers, including oligoethylene glycols, including diethylene glycol, triethylene glycol and tetraethylene glycol; amides, including formamide and monoalkyl formamides and acetamides, wherein the alkyl group may contain 1 to 8 or 1 to 3 carbon atoms, including methyl formamide; dialkylsulfoxide, wherein the alkyl group may contain 1 to 8 or 1 to 3 carbon atoms, including dimethylsulfoxide (DMSO); sulfones, including sulfolane; hydroxy esters, including lactates, including methyl and ethyl lactate; aminic compounds, including ethylenediamine, monoethanolamine, diethanolamine and triethanolamine; carbonate compounds, including propylene carbonate and glycerol carbonate; and cycloalkanone compounds, including dihydrolevoglucosenone. Further, said glycol ethers may include polyethylene glycols (PEG) which may have a molecular weight of 200 to 1,000 g/mole or 200 to 700 g/mole. Preferably, said washing solvent a) comprises one or more of water and above-mentioned diols and triols, in specific monoethylene glycol (MEG) and glycerol, and glycol ethers, in specific diethylene glycol, triethylene glycol and tetraethylene glycol. Further, in specific, said glycol ethers may include polyethylene glycols (PEG) which may have a molecular weight of 200 to 1,000 g/mole or 200 to 700 g/mole. More preferably, washing solvent a) comprises water, most preferably consists of water. In accordance with the present invention, washing solvent a) may comprise one or more solvents which are not mentioned above in combination with one or more solvents which are mentioned above, for example water, wherein the relative amount of the latter solvent(s) may vary within wide ranges and may be as low as for example 0.1 wt.% based on total washing solvent.

[0072] Further, in the present invention, washing solvent a), for example water, may have a pH above 7 ("alkaline"), a pH below 7 ("acid") or a pH of about 7 ("neutral").

[0073] It may be preferred that washing solvent a), for example water, has a pH above 7, more preferably of from 8 up to greater than 14, preferably of from 8 to 14, more preferably of from 10 to 14, most preferably of from 12 to 14.

Such washing solvent having such pH may be provided by adding one or more salts selected from the group consisting of alkali metal carbonates and bicarbonates, including sodium bicarbonate, sodium carbonate, lithium carbonate, lithium bicarbonate, potassium carbonate and potassium bicarbonate, and alkali metal or alkaline earth metal hydroxides, including lithium hydroxide, sodium hydroxide, potassium hydroxide and calcium hydroxide, and ammonium hydroxide.

[0074] Further, it may be preferred that washing solvent a), for example water, has a pH below 7, more preferably of from lower than 1 to 6, more preferably of from 1 to 6, more preferably of from 2 to 5, most preferably of from 2 to 4. Such washing solvent having such pH may be provided by adding an inorganic acid (mineral acid) or an organic acid. Suitably, one or more inorganic acids selected from the group consisting of hydrochloric acid, nitric acid, phosphoric acid, boric acid, perchloric acid, hydrofluoric acid, hydroiodic acid and sulfuric acid may be added. And/or, suitably, one or more organic acids selected from the group consisting of sulfonic acids, including methane sulfonic acid and p-toluene sulfonic acid, and carboxylic acids, including formic acid, oxalic acid, acetic acid, lactic acid, uric acid, malic acid, tartaric acid and citric acid, may be added.

[0075] Still further, it may be preferred that washing solvent a), for example water, has a pH of about 7.

[0076] In a case wherein steps i) to iii) of the present process are repeated 2 or more times, it is preferred that washing solvent a), for example water, to be provided to a first step i) has a pH above 7, more preferably of from 8 up to greater than 14, more preferably of from 8 to 14, more preferably of from 10 to 14, most preferably of from 12 to 14, and washing solvent a), for example water, to be provided to a later step i) and optionally to any subsequent step i) has a pH in the range of from 6 to 8, preferably about 7.

[0077] Extraction solvent b) may have a Hansen solubility parameter distance $R_{a,heptane}$ with respect to heptane as determined at 25 °C of at least 3 $MPa^{1/2}$, preferably at least 5 $MPa^{1/2}$, more preferably at least 10 $MPa^{1/2}$, more preferably at least 15 $MPa^{1/2}$. Further, said $R_{a,heptane}$ for extraction solvent b) may be lower than 45 $MPa^{1/2}$ or at most 40 $MPa^{1/2}$, preferably at most 35 $MPa^{1/2}$, more preferably at most 30 $MPa^{1/2}$, more preferably at most 25 $MPa^{1/2}$. For example, said $R_{a,heptane}$ for N-methylpyrrolidone (NMP) is 15 $MPa^{1/2}$.

[0078] Still further, said extraction solvent b) may have a difference in Hansen solubility parameter distance $R_{a,heptane}$ with respect to heptane compared to Hansen solubility parameter distance $R_{a,toluene}$ with respect to toluene (i.e. $R_{a,heptane} - R_{a,toluene}$) as determined at 25 °C of at least 1.5 $MPa^{1/2}$, preferably at least 2 $MPa^{1/2}$. Further, said difference in $R_{a,heptane}$ compared to $R_{a,toluene}$ for extraction solvent b) may be at most 4.5 $MPa^{1/2}$, preferably at most 4 $MPa^{1/2}$.

[0079] Hansen solubility parameters (HSP) can be used as a means for predicting the likeliness of one component compared to another component. More specifically, each component is characterized by three Hansen parameters, each generally expressed in $MPa^{0.5}$: δ_d, denoting the energy from dispersion forces between molecules; δ_p, denoting the energy from dipolar intermolecular forces between molecules; and δ_h, denoting the energy from hydrogen bonds between molecules. The affinity between compounds can be described using a multidimensional vector that quantifies these solvent atomic and molecular interactions, as a Hansen solubility parameter (HSP) distance R_a which is defined in Equation (1):

$$(R_a)^2 = 4(\delta_{d2} - \delta_{d1})^2 + (\delta_{p2} - \delta_{p1})^2 + (\delta_{h2} - \delta_{h1})^2 \quad (1)$$

wherein

R_a = distance in HSP space between compound 1 and compound 2 ($MPa^{0.5}$)
δ_{d1}, δ_{p1}, δ_{h1} = Hansen (or equivalent) parameter for compound 1 (in $MPa^{0.5}$)
δ_{d2}, δ_{p2}, δ_{h2} = Hansen (or equivalent) parameter for compound 2 (in $MPa^{0.5}$)

[0080] Thus, the smaller the value for R_a for a given solvent calculated with respect to the compound to be recovered (i.e., the compound to be recovered being compound 1 and the solvent being compound 2, or vice versa), the higher the affinity of this solvent for the compound to be recovered will be.

[0081] Hansen solubility parameters for numerous solvents can be found in, among others, CRC Handbook of Solubility Parameters and Other Cohesion Parameters, Second Edition by Allan F.M. Barton, CRC press 1991; Hansen Solubility Parameters: A User's Handbook by Charles M. Hansen, CRC press 2007.

[0082] In specific, extraction solvent b) may comprise ammonia or, preferably, one or more organic solvents selected from the group consisting of diols and triols, including monoethylene glycol (MEG), monopropylene glycol (MPG), any isomer of butanediol and glycerol; glycol ethers, including oligoethylene glycols, including diethylene glycol, triethylene glycol and tetraethylene glycol, and monoalkyl ethers thereof, including diethylene glycol ethyl ether; amides, including N-alkylpyrrolidone, wherein the alkyl group may contain 1 to 8 or 1 to 3 carbon atoms, including N-methylpyrrolidone (NMP), formamide and di- and monoalkyl formamides and acetamides, wherein the alkyl group may contain 1 to 8 or 1 to 3 carbon atoms, including dimethyl formamide (DMF), methyl formamide and dimethyl acetamide; dialkylsulfoxide, wherein the alkyl group may contain 1 to 8 or 1 to 3 carbon atoms, including dimethylsulfoxide (DMSO); sulfones, including sulfolane; N-formyl morpholine (NFM); furan ring containing components and derivatives thereof, including furfural, 2-methyl-furan, furfuryl alcohol and tetrahydrofurfuryl alcohol; hydroxy esters, including lactates, including methyl and ethyl lactate; trialkyl phosphates, including triethyl phosphate; phenolic compounds, including phenol and guaiacol; benzyl alcoholic compounds, including benzyl alcohol; aminic compounds, including ethylenediamine, monoethanolamine, diethanolamine and triethanolamine; nitrile compounds, including acetonitrile and propionitrile; trioxane compounds, including 1,3,5-trioxane; carbonate compounds, including propylene carbonate and glycerol carbonate; and cycloalkanone compounds, including dihydrolevoglucosenone.

[0083] More preferably, said extraction solvent b) comprises one or more of above-mentioned dialkylsulfoxide, in specific DMSO; sulfones, in specific sulfolane; above-mentioned N-alkylpyrrolidone, in specific NMP; and a furan ring containing component, in specific furfural. Even more preferably, said extraction solvent b) comprises one or more of above-mentioned N-alkylpyrrolidone, in specific NMP, and a furan ring containing component, in specific furfural. Most preferably, extraction solvent b) comprises NMP.

[0084] Extraction solvent b) may also include a small amount of water, for example at least 0.5 wt.% or at least 1 wt.%. Suitably, extraction solvent b) contains no more than 10 wt.%, preferably no more than 5 wt.% of water. For example, extraction solvent b) may be NMP containing at least 0.5 wt.% or at least 1 wt.% and no more than 10 wt.% or no more than 5 wt.% of water.

[0085] Washing solvent c) may be a solvent as defined for washing solvent a) in the present specification. In specific, washing solvents a) and c) may be identical. Preferably, washing solvents a) and c) both comprise water. It is preferred that washing solvent c), for example water, has a pH of about 7. In case washing solvent a) and/or washing solvent c) comprise(s) water, said water is preferably demineralized water. This preference applies especially to a case wherein the treated recycled or renewable organic material is to be sent to a further, downstream process for use or conversion. Such demineralized water may be water having a resistivity of at least 0.1 $M\Omega \cdot cm$ and a conductivity of at most 1 $\mu S \cdot cm^{-1}$; or water having a content of scale producing substances in the form of calcium, magnesium carbonates, bicarbonates and silica of less than about twenty parts per million (i.e. water purity above 99.9980%); or water produced by a reverse osmosis or deionization purification process that removes scale producing substances.

[0086] It is preferred that washing solvent a) and extraction solvent b) are not identical. In specific, it is preferred that the miscibilities, in heptane, of washing solvent a) and extraction solvent b) are different. Further, in specific, washing solvent a) may have a Hansen solubility parameter distance $R_{a,heptane}$ with respect to heptane as determined at 25 °C which is greater than such $R_{a,heptane}$ for extraction solvent b). Preferably, said difference in $R_{a,heptane}$ for solvents a) and b) is at least 1 $MPa^{1/2}$, more preferably at least 5 $MPa^{1/2}$, more preferably at least 10 $MPa^{1/2}$, more preferably at least 15 $MPa^{1/2}$, more preferably at least 20 $MPa^{1/2}$, more preferably at least 25 $MPa^{1/2}$. Further, preferably, said difference in $R_{a,heptane}$ for solvents a) and b) is at most 55 $MPa^{1/2}$, more preferably at most 50 $MPa^{1/2}$, more preferably at most 45 $MPa^{1/2}$, more preferably at most 40 $MPa^{1/2}$, more preferably at most 35 $MPa^{1/2}$, more preferably at most 30 $MPa^{1/2}$.

[0087] When the contaminants to be removed from the contaminated recycled or renewable organic material comprise organic chlorides, it is preferred that, after steps i) to iv) or after optional steps v) to viii) have been carried out a suitable number of times, the total amount of organic chloride contaminant in the remaining recycled or renewable organic material in the vessel is less than 10 ppmw, preferably no more than 5 ppmw, more preferably at most 1 ppmw on the basis of the overall weight of the recycled or renewable organic material in the vessel.

[0088] At this stage, an amount of the first or second solvent may be retained in the remaining recycled or renewable organic material. Typically, the content of said solvent in the remaining recycled or renewable organic material will be no more than 20 wt.% or no more than 10 wt.% or no more than 8 wt.%, based on the overall weight of the remaining recycled or renewable organic material. Suitably, such first or second solvent may be removed from the remaining recycled or renewable organic material in optional steps v) to vii) by the second solvent or in optional steps ix) to xii) by the third solvent.

[0089] In a further advantageous embodiment of the invention, at least a portion of the solvent phase removed from the vessel in step iii) or in optional step vii) and containing extraction solvent b), is contacted with a demixing solvent d) .

[0090] Demixing solvent d) may be a solvent as defined for washing solvent c) in the present specification.

[0091] In this embodiment, the above-mentioned removed extraction solvent b) containing phase may be contacted with at least a portion of a washing solvent c) containing phase (A) removed in optional step vii) in case steps i) to iv) are performed using extraction solvent b) as first solvent and steps v) to viii) are performed using washing solvent c) as second solvent, or (B) removed in optional step xi) in case steps v) to viii) are performed using extraction solvent b) as second solvent and steps ix) to xii) are performed using washing solvent c) as third solvent.

[0092] Still further, in this embodiment, the above-mentioned removed extraction solvent b) containing phase may be contacted with at least a portion of a washing solvent a) containing phase removed in step iii), in case steps i) to iv) are performed using washing solvent a) as first solvent and optional steps v) to viii) are performed using extraction solvent b) as second solvent.

[0093] In this embodiment, advantageously, demixing solvent d) may act as anti-solvent for contaminants dissolved in the removed extraction solvent b) containing phase. After mixing, a separate contaminants-containing phase, which is preferably the upper phase (top phase), and a separate phase comprising demixing solvent d) and extraction solvent b) may form. These phases may then be separated from each other by decanting.

[0094] Advantageously, any aromatic hydrocarbons and conjugated aliphatic compounds having two or more carbon-carbon double bonds removed as contaminants in this embodiment, may be blended with pygas and processed into fuel or used in the production of aromatic compounds. Likewise, removed heteroatom containing organic compounds removed may also be converted into fuel, optionally after a hydrotreatment to remove the heteroatoms. Further, said compounds thus removed may be further separated into various fractions which may be used as a solvent.

[0095] In this embodiment, the above-mentioned phase comprising demixing solvent d) and extraction solvent b) can be further separated by distillation at atmospheric pressure or sub-atmospheric pressure into extraction solvent b) and another solvent. These separated solvents may then be recycled and re-used in the process of the present invention as extraction solvent b) and as washing solvent a) or c) or demixing solvent d), respectively. As up to 10 wt.% of the other solvent (e.g. water) may be present in the recycle extraction solvent b), so that the above further separation need not be perfect.

Detailed description of the drawings

[0096] The process of the present invention is illustrated schematically in Figure 1.

[0097] In Figure 1, each of the vessels as drawn (1a, 1b, 1c, 1d, 1e, 1f) represent the same vessel in which all of steps i) to viii) are carried out.

[0098] In the first set of steps i) to iii), an extraction solvent (3) is added to the vessel (1a) containing a contaminated plastics pyrolysis oil and mixed with the plastics pyrolysis oil present in said vessel (1a). After a period of time the mixing is stopped and an upper phase comprising plastics pyrolysis oil (2) and a bottom phase (4) comprising at least a portion of said extraction solvent and at least a portion of the contaminants are allowed to form. The bottom phase (4) is removed from the vessel (1a) through a pipe (5).

[0099] These steps are then repeated in the same vessel (1b, 1c) one or more times. In this exemplary embodiment, the three steps are carried out a total of 3 times.

[0100] The remaining plastics pyrolysis oil (6) in the same vessel (1d) is mixed with an aqueous stream (7). After a period of time the mixing is stopped and an upper phase comprising plastics pyrolysis oil (8) and an aqueous bottom phase (9) are allowed to form. The aqueous bottom phase (9) is removed from the vessel (1d) through a pipe (10).

[0101] At least a portion of the combined (13) extraction solvent bottom phases (4) are then combined and mixed with a portion of the combined (12) aqueous bottom phases (9) in a separate vessel (14).

[0102] The water in the aqueous bottom phase acts as anti-solvent for the contaminants dissolved in the extraction solvent bottom phase. After mixing, a lighter organic phase (15) will separate from a recycle bottom phase (16) comprising the remaining aqueous bottom phase and the extraction solvent bottom phase.

[0103] Said lighter organic phase may be removed by decanting (17) .

[0104] Once this stage of the process has been repeated a number of times, the final recycle bottom phase (16) can be separated and sent via an outlet (18) to a distillation column operating at atmospheric pressure or sub-atmospheric pressure in order to prepare an extraction solvent recycle stream and an aqueous recycle stream.

[0105] Figure 2 shows an exemplary embodiment of a vessel (1) to be used in the process of the present invention.

[0106] The vessel (1) is fitted with at least one inlet (19) and at least one outlet (20) allowing the ingress and egress of fluids into the vessel (1). The vessel (1) is also fitted with a re-circulation system including an outlet from the vessel (21) a pump (22) and an inlet into the vessel (23) to allow mixing of the contents of the vessel. An inlet into the recirculation system (24) may be provided either before or after the pump (22) to allow addition of the extraction solvent and/or washing solvent.

Upstream and downstream integration

[0107] In the present invention, the contaminated recycled or renewable organic material may comprise at least part of a hydrocarbon product formed in a process comprising cracking of plastics, preferably waste plastics, more preferably mixed waste plastics, wherein at least part of the plastics comprises heteroatom containing organic compounds.

[0108] Accordingly, the present invention also relates to a process for the recovery of aliphatic hydrocarbons from plastics, wherein at least part of the plastics comprises heteroatom containing organic compounds, said process comprising the steps of:

(I) cracking the plastics and recovering a hydrocarbon product comprising aliphatic hydrocarbons, heteroatom containing organic compounds and optionally aromatic hydrocarbons; and

(II) subjecting a liquid hydrocarbon feedstock, which comprises at least part of the hydrocarbon product obtained in step (I), to the above-described process for the removal of contaminants from contaminated recycled or renewable organic material in a vessel.

[0109] The preferences and embodiments as described above with reference to the present contaminants removal process as such also apply to step (II) of the present process for the recovery of aliphatic hydrocarbons from plastics. In above-mentioned step (I), the resulting hydrocarbon product may be either a liquid or a solid or wax. In the latter case, the solid or wax is first heated to make it liquid, before subjecting it to the aliphatic hydrocarbons recovery process in step (II).

[0110] In the above-mentioned process, at least part of the plastics as fed to step (I) comprises heteroatom containing organic compounds, which plastics are preferably waste plastics, more preferably mixed waste plastics. In said step (I), the cracking of the plastics may involve a thermal cracking process and/or a catalytic cracking process. The cracking temperature in step (I) may be of from 300 to 800 °C, suitably of from 400 to 800 °C, more suitably of from 400 to 700 °C, more suitably of from 500 to 600 °C. Further, any pressure may be applied, which pressure may be sub-atmospheric, atmospheric or super-atmospheric. Heat treatment in step (I) causes melting of the plastics and cracking of its molecules into smaller molecules. The cracking in step (I) may be carried out as pyrolysis or as liquefaction. Both in pyrolysis and in liquefaction a continuous liquid phase is formed. In addition, in pyrolysis a discontinuous gas phase is formed that escapes the liquid phase and segregates into a continuous gas phase. In liquefaction, there is no significant gas phase by applying a relatively high pressure.

[0111] Further, in step (I), subsequent condensation of a gas phase and/or cooling of a liquid phase provides a hydrocarbon product, which may be either a liquid or a solid or wax, comprising aliphatic hydrocarbons, heteroatom containing organic compounds and optionally aromatic hydrocarbons, at least part of which is subjected to the above-described aliphatic hydrocarbons recovery process in step (II).

[0112] Above-described step (I) may be carried out in any known way, for example in a way as disclosed in WO2018069794 or in WO2017168165, the disclosures of which are herein incorporated by reference.

[0113] Advantageously, aliphatic hydrocarbons as recovered in one of the above-described processes, which may comprise varying amounts of aliphatic hydrocarbons within a wide boiling point range, may be fed to a steam cracker without a further pre-treatment, such as treatment with hydrogen (hydrotreating or hydroprocessing). In addition to being used as a feed to a steam cracker, said recovered aliphatic hydrocarbons may also advantageously be fed to other refining processes including hydrocracking, isomerization, hydrotreating, thermal catalytic cracking and fluid catalytic cracking. Further, in addition to being used as a feed to a steam cracker, said recovered aliphatic hydrocarbons may also advantageously be separated into different fractions which each may find a different application, such as diesel, marine fuel, solvent, etc.

[0114] Accordingly, the present invention also relates to a process for steam cracking a hydrocarbon feed, wherein the hydrocarbon feed comprises aliphatic hydrocarbons as recovered in one of the above-described processes. Further, accordingly, the present invention also relates to a process for steam cracking a hydrocarbon feed, comprising the steps of: recovering aliphatic hydrocarbons from a liquid hydrocarbon feedstock in one of the above-described processes; and steam cracking a hydrocarbon feed which comprises aliphatic hydrocarbons as recovered in the preceding step. The hydrocarbon feed to the steam cracking process may also comprise hydrocarbons from another source, other than the present processes for the recovery of aliphatic hydrocarbons. Such other source may be naphtha, hydrowax or a combination thereof.

[0115] Advantageously, in a case wherein the liquid hydrocarbon feedstock comprises aromatic hydrocarbons, especially polycyclic aromatics, heteroatom containing organic compounds, conjugated aliphatic compounds having two or more carbon-carbon double bonds, or a combination thereof, these have already been removed by the present contaminants removal process as described above before feeding recovered hydrocarbons to a steam cracking process. This is particularly advantageous in that said removed compounds, especially polycyclic aromatics, can no longer cause fouling in the preheat, convection and radiant sections of a steam cracker and in the downstream heat exchange and/or separation equipment for a steam cracker, for example in transfer line exchangers (TLEs) which are used to rapidly cool the effluent from a steam cracker. When hydrocarbons condense, they may thermally decompose into a coke layer which may cause fouling. Such fouling is a major factor determining the run length of the cracker. Reducing the amount of fouling results in longer run times without maintenance shutdowns, and improved heat transfer in the exchangers.

[0116] The steam cracking may be performed in any known way. The hydrocarbon feed is typically preheated. The feed can be heated using heat exchangers, a furnace or any other combination of heat transfer and/or heating devices. The feed is steam cracked in a cracking zone under cracking conditions to produce at least olefins (including ethylene) and hydrogen. The cracking zone may comprise any cracking system known in the art that is suitable for cracking the feed. The cracking zone may comprise one or more furnaces, each dedicated for a specific feed or fraction of the feed.

[0117] The cracking is performed at elevated temperatures, preferably in the range of from 650 to 1000 °C, more preferably of from 700 to 900 °C, most preferably of from 750 to 850 °C. Steam is usually added to the cracking zone, acting as a diluent to reduce the hydrocarbon partial pressure and thereby enhance the olefin yield. Steam also reduces the formation and deposition of carbonaceous material or coke in the cracking zone. The cracking occurs in the absence of oxygen. The residence time at the cracking conditions is very short, typically in the order of milliseconds.

[0118] From the cracker, a cracker effluent is obtained that may comprise aromatics (as produced in the steam cracking process), olefins, hydrogen, water, carbon dioxide and other hydrocarbon compounds. The specific products obtained depend on the composition of the feed, the hydrocarbon-to-steam ratio, and the cracking temperature and furnace residence time. The cracked products from the steam cracker are then passed through one or more heat exchangers, often referred to as TLEs ("transfer line exchangers"), to rapidly reduce the temperature of the cracked products. The TLEs preferably cool the cracked products to a temperature in the range of from 400 to 550 °C.

Claims

1. A process for the removal of contaminants from contaminated recycled or renewable organic material, comprising the steps of:

i) providing a first solvent to a vessel containing the recycled or renewable organic material;
ii) mixing the recycled or renewable organic material and the first solvent and then allowing a solvent phase, comprising at least a portion of the first solvent and at least a portion of the contaminants, and an oil phase, comprising at least a portion of the recycled or renewable organic material, to form;
iii) removing at least a portion of the solvent phase from the vessel and retaining at least a portion of the oil phase in the vessel; and
iv) optionally repeating steps i) to iii) one or more times.

2. The process according to claim 1, further comprising the following steps after step iii) or iv):

v) providing a second solvent to the vessel containing the recycled or renewable organic material;
vi) mixing the recycled or renewable organic material and the second solvent and then allowing a solvent phase, comprising at least a portion of the second solvent and at least a portion of the contaminants, and an oil phase, comprising at least a portion of the recycled or renewable organic material, to form;
vii) removing at least a portion of the solvent phase from the vessel and retaining at least a portion of the oil phase in the vessel; and
viii) optionally repeating steps v) to vii) one or more times.

3. The process according to claim 2, further comprising the following steps after step vii) or viii):

ix) providing a third solvent to the vessel containing the recycled or renewable organic material;
x) mixing the recycled or renewable organic material and the third solvent and then allowing a solvent phase, comprising at least a portion of the third solvent and at least a portion of the contaminants, and an oil phase, comprising at least a portion of the recycled or renewable organic material, to form;
xi) removing at least a portion of the solvent phase from the vessel and retaining at least a portion of the oil phase in the vessel; and
xii) optionally repeating steps ix) to xi) one or more times.

4. The process according to any one of claims 1 to 3, wherein the mixing is carried out by removing a portion of the contents of the vessel at one point of the vessel; circulating said portion via external piping; and returning it to the vessel at a different point.

5. The process according to claim 4, wherein the first solvent and/or optional second solvent and/or optional third solvent is or are provided to the vessel by being added at a point in the external piping.

6. The process according to any one of claims 1 to 5, wherein the recycled or renewable organic material comprises plastics pyrolysis oil.

7. A process for the recovery of aliphatic hydrocarbons from plastics, wherein at least part of the plastics comprises heteroatom containing organic compounds, said process comprising the steps of:

(I) cracking the plastics and recovering a hydrocarbon product comprising aliphatic hydrocarbons, heteroatom containing organic compounds and optionally aromatic hydrocarbons; and
(II) subjecting a liquid hydrocarbon feedstock, which comprises at least part of the hydrocarbon product obtained

in step (I), to the process of any one of claims 1-6.

8. Process for steam cracking a hydrocarbon feed, wherein the hydrocarbon feed comprises aliphatic hydrocarbons as recovered in a process according to any one of claims 1-7.

9. Process for steam cracking a hydrocarbon feed, comprising the steps of:

recovering aliphatic hydrocarbons from a liquid hydrocarbon feedstock in a process according to any one of claims 1-7; and
steam cracking a hydrocarbon feed which comprises aliphatic hydrocarbons as recovered in the preceding step.

Figure 1

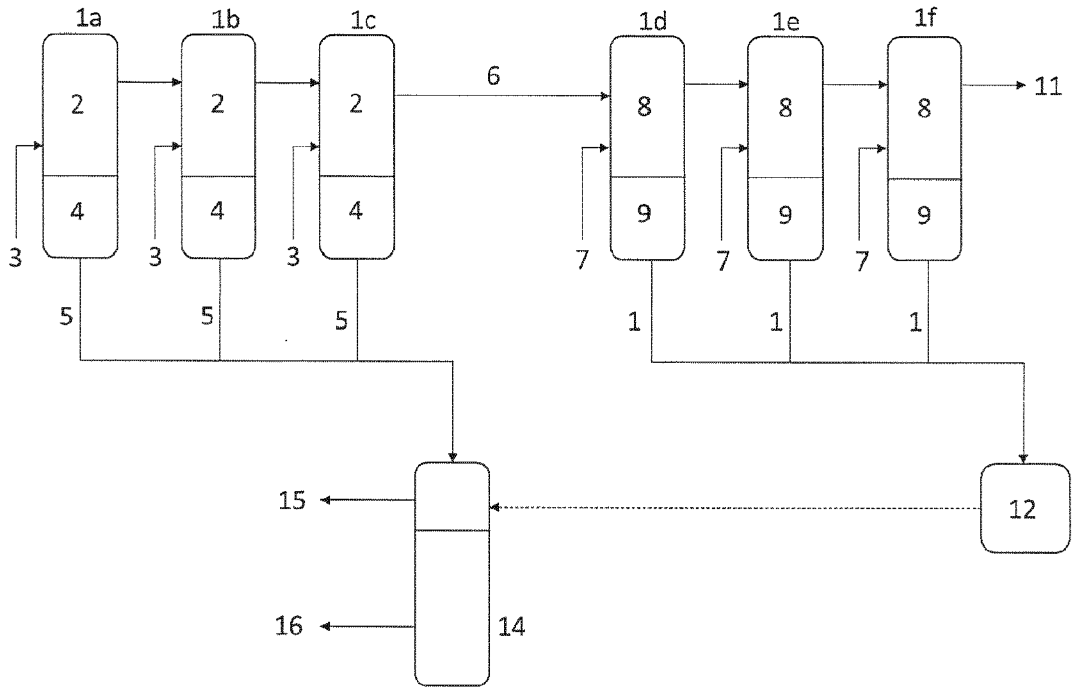
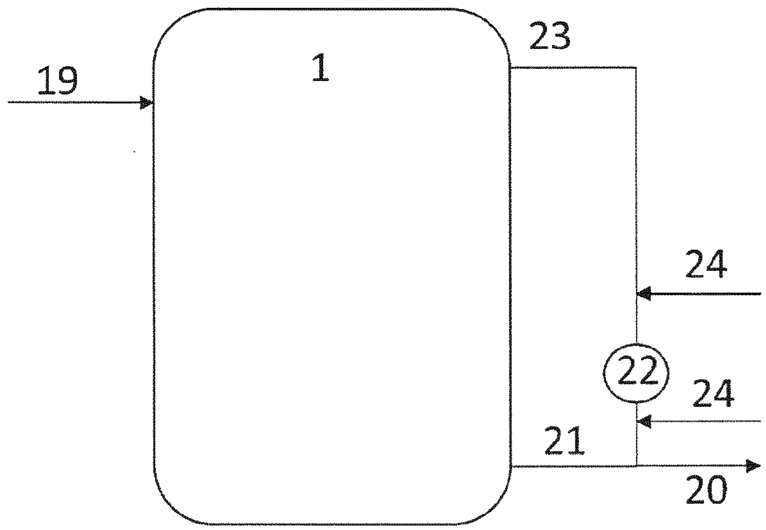


Figure 2



Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 21 15 3966

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2009/301937 A1 (DUYVESTEYN WILLEM P C [US] ET AL) 10 December 2009 (2009-12-10) * claims 1, 2 * * paragraph [0090] * -----	1-3	INV. C10G1/00 C10G1/10 C10G21/00 C10G21/02 C10G55/04
X	WO 2020/178597 A1 (OXFORD SUSTAINABLE FUELS LTD [GB]) 10 September 2020 (2020-09-10)	1-3,6,7	
Y	* paragraphs [0088], [0146], [0152] * * claims 1, 11 * -----	4,5,9	
Y	Anonymous: "Production Mixer Industrial Fluids", , 6 June 2019 (2019-06-06), XP055823041, Retrieved from the Internet: URL:https://web.archive.org/web/20190606161650/http://www.sagasnc.com/eng/mixer-fluidi.htm [retrieved on 2021-07-09] * page 1 * -----	4,5	
			TECHNICAL FIELDS SEARCHED (IPC)
X,D	WO 2020/212315 A1 (SHELL INT RESEARCH [NL]; SHELL OIL CO [US]) 22 October 2020 (2020-10-22)	8	C10G
Y	* claims 9, 10 * -----	9	

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	12 July 2021	Pardo Torre, J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 21 15 3966

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

12-07-2021

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2009301937 A1	10-12-2009	US 2009301937 A1	10-12-2009
		US 2012305452 A1	06-12-2012
WO 2020178597 A1	10-09-2020	NONE	
WO 2020212315 A1	22-10-2020	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- WO 2020212315 A **[0003] [0004]**
- WO 2018069794 A **[0112]**
- WO 2017168165 A **[0112]**

Non-patent literature cited in the description

- **ALLAN F.M. BARTON.** CRC Handbook of Solubility Parameters and Other Cohesion Parameters. CRC press, 1991 **[0081]**
- **CHARLES M. HANSEN.** Hansen Solubility Parameters: A User's Handbook. CRC press, 2007 **[0081]**