

HYDROCARBON EXTRACTION PROCESSES UTILIZING A CLEANSING BED**CROSS-REFERENCE TO RELATED APPLICATION**

[0001] This application claims priority to and the benefit of U.S. Provisional Application No. 63/157,295 having a filing date of March 05, 2021, the disclosure of which is incorporated herein by reference in its entirety.

FIELD

[0002] This disclosure relates to processes, equipment, and systems for separating and/or extracting aromatic hydrocarbons from a mixture feed comprising aromatic and non-aromatic hydrocarbons. In particular, this disclosure relates to processes, equipment and systems for separating/or extracting aromatic hydrocarbons from a mixture feed comprising aromatic and non-aromatic hydrocarbons utilizing a cleansing bed. The processes, equipment, and systems of this disclosure are useful, e.g., in producing aromatic hydrocarbon products such as benzene, toluene, xylenes, and non-aromatic hydrocarbon products from a mixture feed comprising aromatic hydrocarbons and non-aromatic hydrocarbons.

BACKGROUND

[0003] Aromatic hydrocarbon products, such as benzene, toluene, xylenes, p-xylene, o-xylene, ethylbenzene, and the like, especially those with high purities, are highly valuable industrial commodities useful for the production of other value-added industrial chemicals. In a modern petrochemical plant, aromatic hydrocarbon products are routinely produced by separating a mixture feed comprising one or more such aromatic hydrocarbons and non-aromatic hydrocarbons. One example of such mixture feed is a reformat stream, which can comprise non-aromatic hydrocarbons at a high concentration, e.g., up to 80 wt%, based on the total weight of the reformat stream. Other examples of such mixture feed include primarily aromatic hydrocarbon streams produced from a xylenes isomerization unit, a transalkylation unit, or a toluene disproportionation unit. Many of the non-aromatic hydrocarbons present in the mixture feeds are co-boilers of the target aromatic hydrocarbons. As such, producing aromatic hydrocarbon products such as benzene, toluene, xylenes, p-xylene, o-xylene, and the like, from the mixture feed, especially at a high purity, is difficult and inefficient, if not infeasible, by using conventional distillation processes and equipment.

[0004] Solvent-assisted separation processes, such as liquid-liquid extraction (“LLE”) processes and extractive distillation (“ED”) processes, have been used in the industry for a long time to separate aromatic hydrocarbons from a mixture feed. In such processes, typically a solvent with high polarity, such as sulfolane, tetraethylene glycol, and the like, is used to

contact the mixture feed in an extraction column. Because aromatic hydrocarbon molecules typically exhibit a higher polarity than non-aromatic hydrocarbons under the separation conditions, aromatic hydrocarbons disproportionately distribute into the polar solvent to form an aromatic hydrocarbons-rich-solvent stream, which can be subsequently separated to produce high-purity aromatic hydrocarbons and a hydrocarbon-lean-solvent stream. The hydrocarbon-lean-solvent stream can then be recycled to the extraction column. Thus, during the operation of a continuous aromatic hydrocarbons extraction separation process, a quantity of polar solvent circulates in the system.

[0005] Overtime, the hydrocarbon-lean-solvent stream recycled to the extraction column can experience a gradual increase of the concentrations of various contaminants during an operation campaign. Such contaminants can include, among others, saturated and unsaturated heavy hydrocarbons, chlorine-containing compounds, silicon-containing compounds, and the like, produced during the extraction process due to high temperature conditions, and/or introduced through the mixture feed. In one example, such contaminants can include green oil products produced upstream of the extraction unit but not fractionated out. Additionally or alternatively, such contaminants can be at least partly sourced from process to process contamination through heat exchanger leaks and tank farm contamination, acute or chronic. In another example, such contaminants can include those produced in a clay treating step of a feed stream to remove olefins or other contaminants. In yet another example, such contaminants can include heavy components in the overhead product of an upstream fractionator, acute or chronic. Still, the solvent regeneration process can produce polymers through thermal and/or chemical degradation, which can form a part of the contaminants. Equipment corrosion can produce certain heavy contaminants as well. Silicon-containing compounds, such as those sourced from antifoam agents that may be injected into the extraction (e.g., the ED) process, can build up in the solvent stream as contaminants due to their high boiling points. Such contaminants, especially if at a high concentration, can reduce solvent capacity and/or selectivity, cause corrosion and/or fouling of the vessels, conduits, valves, pumps, and other equipment, necessitating frequent shut-downs and maintenance, and severely curtail the life of the system. Thus, an aromatic hydrocarbons extraction system is frequently equipped with one or more solvent regeneration units and/or stream purification units, such as steam stripping column, deep vacuum stripping column, sorbent beds, and the like, to reduce contaminants in the hydrocarbon-lean-solvent stream recycled to the extraction column. Alternatively, a portion of the hydrocarbon-lean-solvent stream may be purged from time to time and replaced with another solvent feed stream, for example, in a solvent exchange process between an ED

unit and an LLE unit. All these methods add to significant costs to the capital expenditure of the engineering and construction of a new aromatics plant, and the ongoing operation thereof. Moreover, certain contaminants in the solvent, e.g., those C10-C20 (more particularly C14-C20) organic compounds, can have boiling points not sufficiently high to be removed in a steam stripper column solvent regenerator, and not sufficiently low to be removed as part of the raffinate or extract, and therefore can accumulate in the recycle solvent stream, particularly in an ED process. In an LLE process, though, C10-C20 contaminants can sometimes be completely extracted and removed by the raffinate stream.

[0006] Thus, there is a continued need for improvement for reducing contaminants in the hydrocarbon-lean-solvent stream recycled to the extraction column in aromatic hydrocarbon extraction processes, and/or improvement in the overall aromatic hydrocarbon production processes. This disclosure satisfies this and other needs.

SUMMARY

[0007] It has been found that in an aromatic hydrocarbon extraction process, such as an LLE process or an ED process, a cleansing bed such as an activated carbon bed, an alumina bed, and/or an ion exchange resin bed, can be used to cleanse a portion of a contaminant-containing lean-solvent stream (e.g., a recycle polar solvent stream comprising appreciable quantity of heavy components as a portion of the contaminants) to remove at least a portion of the contaminants in the lean-solvent stream, thereby obtaining an at least partially purified lean-solvent stream, which can be preferably recycled to the extraction column. The use of such cleansing bed(s) in these processes can be a cost-effective, energy-efficient improvement to existing processes for separating aromatic hydrocarbons.

[0008] Thus, a first aspect of this disclosure relates to a process for extracting aromatic hydrocarbons from a mixture feed comprising aromatic hydrocarbons and non-aromatic hydrocarbons. The process can comprise one or more of the following: (A-1) feeding the mixture feed into an extraction column; (A-2) providing a first lean-solvent stream comprising a polar solvent at a concentration of $c(ps)$ wt%, and heavy components at a total concentration of $c(hcom)$ wt%, based on the total weight of the lean-solvent stream, where $75 \leq c(ps) \leq 99.99$; (A-3) obtaining a cleansed first lean-solvent stream by (A3-a) contacting the first lean-solvent stream with a first cleansing bed comprising activated carbon; and (A-4) feeding at least a portion of the cleansed first lean-solvent stream into the extraction column..

[0009] A second aspect of this disclosure relates to a process for extracting aromatic hydrocarbons from a mixture feed comprising aromatic hydrocarbons and non-aromatic hydrocarbons. The process can comprise one or more of the following: (B-1) feeding the

mixture feed into an extractive distillation column; (B-2) providing a first lean-solvent stream comprising a polar solvent at a concentration of $c(\text{ps})$ wt%, and heavy components at a total concentration of $c(\text{hcom})$ wt%, based on the total weight of the lean-solvent stream, where $75 \leq c(\text{ps}) \leq 99.99$; (B-3) obtaining a cleansed first lean-solvent stream by (B3-a) contacting the first lean-solvent stream with an primary cleansing bed comprising an ion exchange resin; and (B-4) feeding at least a portion of the cleansed first lean-solvent stream into the extraction column.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is a schematic diagram showing an exemplary extraction process/system for separating aromatic hydrocarbons from a mixture feed comprising aromatic hydrocarbons and non-aromatic hydrocarbons including a cleansing station to clean a stream of hydrocarbon-lean solvent to produce an aromatics extract stream and a raffinate stream, according to an embodiment of the first aspect of this disclosure.

[0011] FIG. 2 is a schematic diagram showing an exemplary benzene recovery process/system useful for recovering a benzene product stream from a benzene-containing aromatics extract stream, according to various embodiments of the first and/or second aspect of this disclosure.

[0012] FIG. 3 is a diagram showing impurity profiles of effluent samples in the test runs as a function of draining time in Example 3 herein.

DETAILED DESCRIPTION

Definitions

[0013] In the present disclosure, a process is described as comprising at least one “step.” It should be understood that each step is an action or operation that may be carried out once or multiple times in the process, in a continuous or discontinuous fashion. Unless specified to the contrary or the context clearly indicates otherwise, each step in a process may be conducted sequentially in the order as they are listed, with or without overlapping with one or more other step(s), or in any other order, as the case may be. In addition, one or more or even all steps may be conducted simultaneously with regard to the same or different batch of material. For example, in a continuous process, while a first step in a process is being conducted with respect to a raw material just fed into the beginning of the process, a second step may be carried out simultaneously with respect to an intermediate material resulting from treating the raw materials fed into the process at an earlier time in the first step. Preferably, the steps are conducted in the order described.

[0014] Unless otherwise indicated, all numbers indicating quantities in the present disclosure are to be understood as being modified by the term “about” in all instances. It should also be understood that the precise numerical values used in the specification and claims constitute specific embodiments. Efforts have been made to ensure the accuracy of the data in the examples. However, it should be understood that any measured data inherently contain a certain level of error due to the limitation of the technique and equipment used for making the measurement.

[0015] As used herein, the indefinite article “a” or “an” shall mean “at least one” unless specified to the contrary or the context clearly indicates otherwise. Thus, embodiments using “a distillation column” include embodiments where one, two or more distillation columns are used, unless specified to the contrary or the context clearly indicates that only one distillation column is used. Likewise, “a C9+ stream” should be interpreted to include one, two, or more C9+ components, unless specified or indicated by the context to mean only one specific C9+ component.

[0016] As used herein, “wt%” means percentage by weight, “vol%” means percentage by volume, “mol%” means percentage by mole, “ppm” means parts per million, and “ppm wt” and “wppm” are used interchangeably to mean parts per million on a weight basis. All “ppm”, as used herein, are ppm by weight unless specified otherwise. All concentrations herein are expressed on the basis of the total amount of the composition in question. Thus, e.g., the concentrations of the various components of a feed composition are expressed based on the total weight of the feed composition. All ranges expressed herein should include both end points as two specific embodiments unless specified or indicated to the contrary.

[0017] “Hydrocarbon” means (i) any compound consisting of hydrogen and carbon atoms or (ii) any mixture of two or more such compounds in (i). The term “C_n hydrocarbon,” where n is a positive integer, means (i) any hydrocarbon compound comprising carbon atom(s) in its molecule at the total number of n, or (ii) any mixture of two or more such hydrocarbon compounds in (i). The term “C_n aromatic hydrocarbon,” where n is a positive integer, means (i) any aromatic hydrocarbon compound comprising carbon atom(s) in its molecule at the total number of n, or (ii) any mixture of two or more such aromatic hydrocarbon compounds in (i). Thus, a C₂ hydrocarbon can be ethane, ethylene, acetylene, or mixtures of at least two of them at any proportion. A “C_m to C_n hydrocarbon” or “C_m-C_n hydrocarbon,” where m and n are positive integers and m < n, means any of C_m, C_{m+1}, C_{m+2}, ..., C_{n-1}, C_n hydrocarbons, or any mixtures of two or more thereof. Thus, a “C₂ to C₃ hydrocarbon” or “C₂-C₃ hydrocarbon” can be any of ethane, ethylene, acetylene, propane, propene, propyne, propadiene,

cyclopropane, and any mixtures of two or more thereof at any proportion between and among the components. A “saturated C2-C3 hydrocarbon” can be ethane, propane, cyclopropane, or any mixture thereof of two or more thereof at any proportion. A “C_n+ hydrocarbon” means (i) any hydrocarbon compound comprising carbon atom(s) in its molecule at the total number of at least n, or (ii) any mixture of two or more such hydrocarbon compounds in (i). A “C_n- hydrocarbon” means (i) any hydrocarbon compound comprising carbon atoms in its molecule at the total number of at most n, or (ii) any mixture of two or more such hydrocarbon compounds in (i). A “C_m hydrocarbon stream” means a hydrocarbon stream consisting essentially of C_m hydrocarbon(s). A “C_m-C_n hydrocarbon stream” means a hydrocarbon stream consisting essentially of C_m-C_n hydrocarbon(s). A “C_n+ aromatic hydrocarbon” means (i) any aromatic hydrocarbon compound comprising carbon atom(s) in its molecule at the total number of at least n, or (ii) any mixture of two or more such aromatic hydrocarbon compounds in (i). A “C_n- aromatic hydrocarbon” means (i) any aromatic hydrocarbon compound comprising carbon atoms in its molecule at the total number of at most n, or (ii) any mixture of two or more such aromatic hydrocarbon compounds in (i). A “C_m aromatic hydrocarbon stream” means a hydrocarbon stream consisting essentially of C_m aromatic hydrocarbon(s). A “C_m-C_n aromatic hydrocarbon stream” means a hydrocarbon stream consisting essentially of C_m-C_n aromatic hydrocarbon(s).

[0018] An “aromatic hydrocarbon” is a hydrocarbon comprising an aromatic ring in the molecule structure thereof. A “non-aromatic hydrocarbon” means a hydrocarbon other than an aromatic hydrocarbon.

[0019] “Co-boiler” means a compound having a normal boiling point in proximity to that of a reference compound or product. For example, where a reference compound or product has a normal boiling point of bp °C, a co-boiler thereof can have a normal boiling point in the range of bp±30 °C, bp±25°C, bp±20 °C, bp±15 °C, bp±10°C, or bp±5°C. A co-boiler of a reference compound can have a relative volatility in a range from, e.g., 0.5 to 5, or 0.5 to 3, or 0.5 to 2, or 0.5 to 1.5. Typical co-boilers of benzene include, but are not limited to: methylcyclopentane, cyclohexane, 2,3-dimethylpentane, dimethylcyclopentanes, ethylcyclopentane, and 3-methylhexane. Due to close boiling points, conventional distillation typically cannot be economically used to separate co-boilers from a reference compound or product. Major non-aromatic co-boilers of aromatic hydrocarbons present in petrochemical products and petrochemical process streams tend to comprise linear, branched, and/or cyclic alkanes and olefins at total high concentration thereof of, e.g., ≥ 60 wt%, ≥ 70 wt%, ≥ 80 wt%,

≥ 90 wt%, ≥ 95 wt%, or even ≥ 98 wt%, based on the total weight of the non-aromatic co-boilers.

[0020] “Heavy components” as used herein means components that may be present in a lean-solvent stream differing from the solvent and having a normal boiling point of at least 140 °C, e.g., ≥ 150 °C, ≥ 160 °C, ≥ 180 °C, and even ≥ 200 °C.

[0021] “Xylene,” either in singular or plural form, shall collectively mean one of or any mixture of two or three of para-xylene, meta-xylene, and ortho-xylene at any proportion thereof.

[0022] “Rich” or “enriched” when describing a component in a stream means that the stream comprises the component at a concentration higher than a source material from which the stream is derived. “Depleted” when describing a component in a stream means that the stream comprises the component at a concentration lower than a source material from which the stream is derived. Thus, in embodiments where an admixture stream comprising an aromatic hydrocarbon and a non-aromatic hydrocarbon is separated by a cleansing station comprising a membrane to produce a permeate stream comprising the aromatic hydrocarbon at a higher concentration than the admixture stream and the non-aromatic hydrocarbon at a lower concentration than the admixture stream, the permeate stream is rich or enriched in the aromatic hydrocarbon and depleted in the non-aromatic hydrocarbon relative to the admixture stream.

[0023] “Lean” means depleted. A “lean-solvent,” or “lean solvent,” or “hydrocarbon-lean solvent” in this disclosure interchangeably means a composition or stream depleted in hydrocarbon(s) and consisting essentially of solvent. A “rich-solvent,” “rich solvent,” or “hydrocarbon-rich solvent” in this disclosure interchangeably means a composition or stream comprising solvent and rich in hydrocarbon(s).

[0024] “Consisting essentially of” as used herein means the composition, feed, or effluent comprises a given component at a concentration of at least 60 wt%, preferably at least 70 wt%, more preferably at least 80 wt%, more preferably at least 90 wt%, still more preferably at least 95 wt%, based on the total weight of the composition, feed, or effluent in question.

[0025] Nomenclature of elements and groups thereof used herein are pursuant to the Periodic Table used by the International Union of Pure and Applied Chemistry after 1988. An example of the Periodic Table is shown in the inner page of the front cover of Advanced Inorganic Chemistry, 6th Edition, by F. Albert Cotton et al. (John Wiley & Sons, Inc., 1999).

Liquid-Liquid Extraction Processes for Separating a Mixture Feed Comprising Aromatic Hydrocarbons and Non-Aromatic Hydrocarbons

[0026] Liquid-liquid extraction (“LLE”) processes have been used to separate aromatic hydrocarbons from a mixture comprising aromatic and non-aromatic hydrocarbons. An LLE

unit can include a LLE column receiving a feed mixture stream at one location on the column and a polar solvent stream at another location above the feed mixture stream. The solvent stream typically flows downwards to mix with the feed mixture. The polar solvent, e.g., sulfolane, preferentially extracts the aromatic hydrocarbons, due to their higher polarity than the non-aromatic hydrocarbons, to form a rich-solvent stream rich in aromatic hydrocarbons relative to the feed mixture stream exiting the bottom of the column. Non-aromatic hydrocarbons then preferentially flow upwards and exit as an overhead stream. An LLE column is operated at relatively low temperature such that substantially all materials in the column are in liquid phase. An overall LLE unit can also include additional equipment such as one or more stripping column for processing the overhead stream and the rich-solvent stream, and at least one recovery column for recovering high-purity aromatic hydrocarbons from a mixture of the polar solvent and the aromatic hydrocarbons, which also produces a lean-solvent stream. The lean solvent may be partly regenerated and/or cleaned, and then recycled to the LLE column.

[0027] Description of exemplary liquid-liquid extraction equipment and process can be found in, e.g., U.S. Patent Nos. 4,039,389 and 6,569,390, the relevant contents of both of which are incorporated herein by reference.

Extractive distillation Processes for Separating a Mixture Feed Comprising Aromatic Hydrocarbons and Non-Aromatic Hydrocarbons

[0028] Extractive distillation (“ED”) processes have been used to separate aromatic hydrocarbons from a mixture comprising aromatic and non-aromatic hydrocarbons as well. An ED unit can include an ED column receiving a feed mixture stream at one location on the column and a polar solvent stream at another location above the feed mixture stream. The solvent stream typically flows downwards to mix with the feed mixture. The polar solvent, e.g., sulfolane, preferentially extracts the aromatic hydrocarbons, due to their higher polarity than the non-aromatic hydrocarbons, to form a rich-solvent stream in liquid phase and rich in aromatic hydrocarbons relative to the feed mixture stream exiting the bottom of the column. Non-aromatic hydrocarbons then preferentially flow upwards and exit as an overhead stream in vapor phase. In comparison to an LLE column, an ED column is operated at higher temperature such that the overhead effluent is substantially in vapor phase. An overall ED unit can also include additional equipment such as one or more stripping column for processing the overhead stream and the rich-solvent stream, and at least one recovery column for recovering high-purity aromatic hydrocarbons from a mixture of the polar solvent and the aromatic

hydrocarbons, which also produces a lean-solvent stream. The lean solvent may be partly regenerated and/or cleaned, and then recycled to the ED column.

[0029] Description of exemplary extractive distillation equipment and process can be found in, e.g., WO2012/135111; U.S. Patent Application Publication No. 2010/0270213; U.S. Patent Nos. 3723256; 4,234,544; 4,207,174; and 5,310,480; the relevant contents of all of which are incorporated herein by reference.

Processes of the First Aspect of This Disclosure

[0030] A first aspect of this disclosure relates to process for extracting aromatic hydrocarbons from a mixture feed comprising aromatic hydrocarbons and non-aromatic hydrocarbons, the process comprising:

(A-1) feeding the mixture feed into an extraction column;

(A-2) providing a first lean-solvent stream comprising a polar solvent at a concentration of $c(\text{ps})$ wt%, and heavy components at a total concentration of $c(\text{hcom})$ wt%, based on the total weight of the lean-solvent stream, where $75 \leq c(\text{ps}) \leq 99.99$;

(A-3) obtaining a cleansed first lean-solvent stream by (A3-a) contacting the first lean-solvent stream with a first cleansing bed comprising activated carbon; and

(A-4) feeding at least a portion of the cleansed first lean-solvent stream into the extraction column.

[0031] In certain embodiments of the processes of the first aspect, $c(\text{hcom}) \text{ wt}\% \leq c(\text{sat}) \text{ wt}\%$, where $c(\text{sat}) \text{ wt}\%$ is the saturation concentration of the heavy components in the polar solvent at the temperature of the first lean-solvent stream provided in step (A-2), expressed as weight percentage of the heavy components on the basis of the total weight of the heavy components and the polar solvent; preferably $c(\text{hcom}) \text{ wt}\% < c(\text{sat}) \text{ wt}\%$; preferably $c(\text{hcom}) \text{ wt}\% \leq 0.8 c(\text{sat}) \text{ wt}\%$; preferably $c(\text{hcom}) \text{ wt}\% \leq 0.6 c(\text{sat}) \text{ wt}\%$; preferably $c(\text{hcom}) \text{ wt}\% \leq 0.5 c(\text{sat}) \text{ wt}\%$. "Saturation concentration" is the maximal concentration of a material at a given temperature dissolvable in a solvent to form a homogeneous solution at equilibrium without phase separation. If the heavy components are present in the first lean-solvent stream at a concentration above the saturation concentration thereof, a phase separation occurs to form a phase rich in the heavy components and a solvent phase comprising the heavy components at the saturation concentration. If allowed to settle to a certain extent, the heavy component phase accumulates on the top over the solvent phase due to density difference. Thus, in certain embodiments, where the lean-solvent stream may comprise the heavy components at above the saturation concentration and a phase separation has occurred, one may allow the lean-solvent stream or a split stream thereof to settle in a vessel to a certain extent to form a hydrocarbon

top layer and a bottoms solvent phase layer, decant the top layer, and return the bottoms solvent phase layer to the LLE or ED column, after optionally being treated by using a sorbent bed such as an activated carbon bed, an alumina bed, an ion exchange resin bed, or any mixture or combination thereof, as described above and below suitable for treating a lean-solvent stream. In certain other embodiments, where the lean-solvent stream may comprise the contaminants approximate to (preferably below, but may be above) the saturation concentration and a phase separation has or has not occurred, one may cool the lean-solvent stream or a split stream thereof to a lower temperature having a contaminants saturation concentration lower than the actual concentration of the contaminants in the stream to induce (additional) phase separation, allow the cooled stream to settle in a vessel to a certain extent to form a hydrocarbon top layer and a bottoms solvent phase layer, decant the top layer, and return the bottoms solvent phase layer to the LLE or ED column, after optionally being treated by using a sorbent bed such as an activated carbon bed, an alumina bed, an ion exchange resin bed, or any mixture or combination thereof, as described above and below suitable for treating a lean-solvent stream. Preferably, the first lean-solvent stream has a concentration of the contaminants, such as C10-C20 organic compounds (e.g., C14-C20 compounds, particularly C10-C20 hydrocarbons, and particularly C14-C20 hydrocarbons) no higher than, more preferably below, their saturation concentration in the solvent. In such case, no separate phase of the contaminants exits in the first lean-solvent stream.

[0032] In certain embodiments, step (A-3) further comprises (A-3b) contacting the first lean-solvent stream with a second cleansing bed comprising an ion exchange resin and/or alumina. In certain specific embodiments, in step (A-3b), the second cleansing bed comprises a basic ion exchange resin. In certain embodiments, step (A-3a) precedes step (A-3b), i.e., the first cleansing bed is upstream of the second cleansing bed in the flow of the first lean-solvent stream. In certain embodiments, step (A-3b) precedes step (A-3a), i.e., the second cleansing bed is upstream of the first cleansing bed in the flow of the first lean-solvent stream. The first cleansing bed and the second cleansing bed may be located in a common vessel as separate layers, or in separate vessels. When in a common up-flow or down-flow vessel, either the first cleansing bed or the second cleansing bed can be a top or bottom bed. It is also possible that the first and the second cleansing beds contain mixtures of multiple different kinds of adsorbents such as activated carbon, ion-exchange resins, and alumina.

[0033] Any activated carbon can be used in the first cleansing bed. Powdered activated carbon, granular activated carbon, pelletize activated carbon, extruded activated carbon such as those made from a mixture of powdered activated carbon and a binder, bead activated carbon

such as those made from petroleum pitch, woven carbon, and mixtures and combinations thereof, can all be used. Preferably, the first cleansing bed comprises granular activated carbon or extruded activated carbon, which can be easily loaded and exchanged out when spent. The activated carbon can have surface area varying significantly, e.g., from 1000 to 1500 m²/g, as measured by BET. A high surface area indicates a high porosity, which can be conducive to the adsorption capability. Activated carbon products in various forms mentioned above are commercially available from, e.g., Cabot Corporation, Alpharetta, Georgia, U.S.A.; Chemviron, Parc Industriel De Feluy, Zone C, B-7181 Feluy, Belgium.

[0034] Any ion exchange resin may be used in the second cleansing bed. Preferably the ion exchange resin is an anion exchange resin. Preferably the ion exchange resin is a basic anion exchange resin. More preferably the ion exchange resin is a strong basic anion exchange resin. Non-limiting examples of ion exchange resins useful for the second cleansing bed include: Amberlite[®] IRA-743, Dowex[®] 550A, Purolite[®] A500MBOHINDPlus, Purolite[®] A500MBOHPlus, Purolite[®] A500OHPlus, Purolite[®] A510MBOHINDPlus, Purolite[®] A510MBOHPlus, Purolite[®] PFA400OH, Purolite[®] PFA600OH, Purolite[®] A200MBOH, Purolite[®] A200MBOHIND, Purolite[®] A300MB, Purolite[®] A300OH, Purolite[®] A400MBOH, Purolite[®] A400MBOHIND, Purolite[®] A400OH, Purolite[®] A600MBOH, Purolite[®] A600OH, Puropack[®] PPA400OH, Supergel[™] SGA550OH, Lanxess Corporation LEWATIT[®] ASB 1 OH, LEWATIT[®] MonoPlus M 500 OH, LEWATIT[®] MonoPlus M 800 OH, LEWATIT[®] MonoPlus MP 800 OH, Mitsubishi Chemical Corporation's Diaion[™] SA10AOH (Type I), Diaion[™] SA20AOH (Type II), Diaion[™] PA312LOH (Type I), Diaion[™] UBA120OH, Diaion[™] UBA120OHUP, Diaion[™] UBA100OHUP (Type I), Resin Tech Inc's SBG1P-SBG1-OH, SBG2-OH, Resinex-Jacobo's Resinex[™] A-4 OH, Resinex[™] A-4 UB OH, Resinex[™] A-7 UB OH, Resinex[™] A-25 OH, Resinex[™] AP OH, Resinex[™] AP MB OH, and mixtures and combinations thereof.

[0035] Any alumina may be used in the second cleansing bed. Preferably the alumina is an activated alumina. Activated alumina products can be available from BASF Catalysts Germany GmbH, Nienburg, Germany; and Dynamic Adsorbents Inc., Norcross, Georgia, U.S.A. Non-limiting examples of alumina useful for the second cleansing bed include CPN activated alumina from BASF.

[0036] The extraction column used in step (A-1) can be a liquid-liquid extraction column or an extractive distillation column described above, or a combination of both. Preferably, the extraction column is an extractive distillation column.

[0037] The polar solvent useful in the processes of this disclosure can be any such solvent known in the art. Non-limiting examples of such polar solvent are: tetraethylene glycol, triethylene glycol, diethylene glycol, ethylene glycol, methoxy triglycol ether, diglycolamine, dipropylene glycol, N-formyl morpholine, N-methyl pyrrolidone, 2,3,4,5-tetrahydrothiophene-1,1-dioxide ("sulfolane"), 3-methylsulfolane and dimethyl sulfoxide, tetramethylenesulfone, mixtures thereof, and/or admixtures with water thereof. A particularly preferred polar solvent is sulfolane. Another particularly preferred polar solvent is tetraethylene glycol.

[0038] To facilitate effective and efficient cleansing in the cleansing station, the first lean-solvent stream (e.g., where the solvent is sulfolane) can have a temperature T in a range from, e.g., 25 to 80 °C (e.g., 25 °C, 26 °C, 28 °C, 30 °C, 35 °C, 40 °C, 45 °C, 50 °C, 55 °C, 60 °C, 70 °C, 72 °C, 74 °C, 75 °C, 76 °C, 78 °C, or 80 °C) when fed into the cleansing station. In embodiments where tetraethylene glycol is used as the polar solvent, the first lean-solvent stream can have a temperature in range from e.g., 115 to 125 °C.

[0039] The first lean-solvent stream can comprise the polar solvent (e.g., where the solvent is sulfolane) at a concentration of $c(\text{ps})$ wt%, and the heavy components at a total concentration of $c(\text{hcom})$ wt%, based on the total weight of the lean-solvent stream, where $c(\text{ps})$ can range from $c(\text{ps})_1$ to $c(\text{ps})_2$, $c(\text{ps})_1$ and $c(\text{ps})_2$ can be, independently, e.g., 75, 76, 77, 78, 79, 80, 82, 84, 85, 86, 88, 90, 92, 94, 95, 96, 97, 98, 99, 99.9, and 99.99, as long as $c(\text{ps})_1 < c(\text{ps})_2$; and $c(\text{hcom})$ can range from $c(\text{hcom})_1$ to $c(\text{hcom})_2$, and $c(\text{hcom})_1$ and $c(\text{hcom})_2$ can be, independently, e.g., 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 29, 20, as long as $c(\text{hcom})_1 < c(\text{hcom})_2$. Preferably $c(\text{ps})_1 \geq 85$ and $c(\text{hcom})_2 \leq 15$. Preferably $c(\text{ps})_1 \geq 90$ and $c(\text{hcom})_2 \leq 10$. Preferably $c(\text{ps})_1 \geq 92$ and $c(\text{hcom})_2 \leq 8$.

[0040] In certain embodiments of the process of the first aspect, the process further comprises (A-5) feeding a second lean-solvent stream comprising the polar solvent into the extraction column. In certain specific embodiments, in a given time period, the first lean-solvent stream comprises the polar solvent (e.g., where the solvent is sulfolane) at a total weight of W_1 , the second lean-solvent stream comprises the polar solvent at a total weight of W_2 , and $0.5\% \leq W_1/(W_1+W_2) * 100\% \leq 10\%$. The value of $W_1/(W_1+W_2) * 100\%$ may range from $r_1\%$ to $r_2\%$, where r_1 and r_2 can be, independently, e.g., 0.5, 0.6, 0.7, 0.8, 0.9, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Preferably $r_1 = 1$ and $r_2 = 5$. Preferably $r_1 = 1$ and $r_2 = 3$. In these embodiments, compared to the quantity of the polar solvent supplied directly into the extraction column, W_2 , the quantity of the polar solvent in the first lean-solvent stream, subjected to cleansing by the first cleansing bed and optionally the second cleansing bed, W_1 , is relatively small. In certain

specific embodiments, the first lean-solvent stream and the second lean-solvent stream are derived from a common lean-solvent stream, e.g., as two split streams from the common lean-solvent stream. The common lean-solvent stream can be a recycle solvent stream produced from, e.g., a distillation column separating a rich-solvent stream consisting essentially of the polar solvent and aromatic hydrocarbons. Although only a small fraction of the recycle lean-solvent stream is subjected to heavy components abatement using the cleansing station, the cumulative amount of heavy components removed and abated by the cleansing station can be significant over a prolonged operation campaign, capable of significantly increase the service life of the batch of the polar solvent circulating in the extraction system, with or without using additional means to further purify the polar solvent in circulation such as sorbent beds, vacuum regeneration column, and steam stripping solvent regenerator.

[0041] In various embodiments of the process of the first aspect, the process may further comprise: (A-6) obtaining a bottoms stream from the extraction column, wherein the bottoms stream is rich in aromatic hydrocarbons and the polar solvent relative to the mixture feed; (A-7) separating at least a portion of the bottoms stream in a stripping column to obtain an aromatic hydrocarbons-rich stream depleted in the polar solvent relative to the bottoms stream, and a third lean-solvent stream depleted in aromatic hydrocarbons relative to the bottoms stream; and (A-8) deriving at least one of the first lean-solvent stream, the second lean-solvent stream, and the common lean-solvent stream from the third lean-solvent stream. In these embodiments, a circulation loop of the polar solvent exists in the overall process. As discussed above, step (A3) functions to purify at least a portion of the recycle lean-solvent stream to prolong the service life thereof in the overall process and system.

[0042] In certain specific embodiments comprising steps (A-12) to (A-14), the process may further comprise (A-9) deriving a fourth lean-solvent stream from the third lean-solvent stream; (A-10) regenerating the fourth lean-solvent stream in a steam stripping regeneration column and/or a vacuum regeneration column to obtain a regenerated lean-solvent stream comprising steam and a bottoms heavy stream; and (A-11) feeding the regenerated lean-solvent stream into one or more of: the stripping column, the extraction column, and the cleansing station as at least a portion of the first lean-solvent stream. In these embodiments, a regeneration column is utilized to further purify a lean-solvent stream, further prolonging the service life of the polar solvent in the process.

[0043] The activated carbon in the first cleansing bed and the ion exchange resin and/or alumina in the second cleansing bed may be provided with various adsorption capacity. Thus, after a certain period of online operation, the sorbents may become saturated with the

contaminants adsorbed from the first lean-solvent stream. In such case, the sorbent(s) may be changed out and replaced with a fresh batch. Alternatively or additionally, the sorbents may be regenerated in-situ in the cleansing stations without being taken out. Alternatively, the changed out sorbents may be regenerated ex-situ to regain at least a portion of its adsorption capacity, and then reloaded into the cleansing stations where appropriate.

Processes of the Second Aspect of This Disclosure

[0044] A second aspect of this disclosure relates to a process for extracting aromatic hydrocarbons from a mixture feed comprising aromatic hydrocarbons and non-aromatic hydrocarbons, the process comprising: (B-1) feeding the mixture feed into an extractive distillation column; (B-2) providing a first lean-solvent stream comprising a polar solvent at a concentration of $c(\text{ps})$ wt%, and heavy components at a total concentration of $c(\text{hcom})$ wt%, based on the total weight of the lean-solvent stream, where $75 \leq c(\text{ps}) \leq 99.99$; (B-3) obtaining a cleansed first lean-solvent stream by (B3-a) contacting the first lean-solvent stream with a primary cleansing bed comprising an ion exchange resin; and (B-4) feeding at least a portion of the cleansed first lean-solvent stream into the extraction column.

[0045] In certain embodiments, step (B-3) further comprises (B-3b) contacting the first lean-solvent stream with a secondary cleansing bed comprising an activated carbon and/or alumina. In certain embodiments, step (B-3a) precedes step (B-3b), i.e., the primary cleansing bed is upstream of the secondary cleansing bed in the flow of the first lean-solvent stream. In certain embodiments, step (B-3b) precedes step (B-3a), i.e., the secondary cleansing bed is upstream of the primary cleansing bed in the flow of the first lean-solvent stream. The primary cleansing bed and the secondary cleansing bed may be located in a common vessel as separate layers, or in separate vessels. When in a common up-flow or down-flow vessel, either the primary cleansing bed or the secondary cleansing bed can be a top or bottom bed. It is also possible that the primary and the secondary cleansing beds contain mixtures of multiple different kinds of adsorbents such as activated carbon, ion-exchange resins, and alumina.

[0046] Any ion exchange resin bed described above in connection with the second aspect of this disclosure may be used in the primary cleansing bed. Any activated carbon described above in connection with the second aspect of this disclosure can be used in the secondary cleansing bed. Any alumina described above in connection with the second aspect of this disclosure may be used in the secondary cleansing bed.

[0047] Any polar solvent as described above in connection with the second aspect of this disclosure may be used in the processes of the second aspect, mutatis mutandis.

[0048] To facilitate effective and efficient cleansing in the cleansing station(s), the first lean-solvent stream (e.g., where the solvent is sulfolane) can have a temperature T in a range from, e.g., 25 to 80 °C (e.g., 25 °C, 26 °C, 28 °C, 30 °C, 35 °C, 40 °C, 45 °C, 50 °C, 55 °C, 60 °C, 70 °C, 72 °C, 74 °C, 75 °C, 76 °C, 78 °C, or 80 °C) when fed into the cleansing station.

[0049] The first lean-solvent stream can comprise the polar solvent (e.g., where the solvent is sulfolane) at a concentration of $c(\text{ps})$ wt%, and the heavy components at a total concentration of $c(\text{hcom})$ wt%, based on the total weight of the lean-solvent stream, where $c(\text{ps})$ can range from $c(\text{ps})_1$ to $c(\text{ps})_2$, $c(\text{ps})_1$ and $c(\text{ps})_2$ can be, independently, e.g., 75, 76, 77, 78, 79, 80, 82, 84, 85, 86, 88, 90, 92, 94, 95, 96, 97, 98, 99, 99.9, and 99.99, as long as $c(\text{ps})_1 < c(\text{ps})_2$; and $c(\text{hcom})$ can range from $c(\text{hcom})_1$ to $c(\text{hcom})_2$, and $c(\text{hcom})_1$ and $c(\text{hcom})_2$ can be, independently, e.g., 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 29, 20, as long as $c(\text{hcom})_1 < c(\text{hcom})_2$. Preferably $c(\text{ps})_1 \geq 85$ and $c(\text{hcom})_2 \leq 15$. Preferably $c(\text{ps})_1 \geq 90$ and $c(\text{hcom})_2 \leq 10$. Preferably $c(\text{ps})_1 \geq 92$ and $c(\text{hcom})_2 \leq 8$.

[0050] In certain embodiments of the process of the second aspect, the process further comprises (B-5) feeding a second lean-solvent stream comprising the polar solvent into the extraction column. In certain specific embodiments, in a given time period, the first lean-solvent stream comprises the polar solvent at a total weight of W_1 , the second lean-solvent stream comprises the polar solvent at a total weight of W_2 , and $0.5\% \leq W_1/(W_1+W_2) * 100\% \leq 10\%$. The value of $W_1/(W_1+W_2) * 100\%$ may range from $r_1\%$ to $r_2\%$, where r_1 and r_2 can be, independently, e.g., 0.5, 0.6, 0.7, 0.8, 0.9, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Preferably $r_1 = 1$ and $r_2 = 5$. Preferably $r_1 = 1$ and $r_2 = 3$. In these embodiments, compared to the quantity of the polar solvent supplied directly into the extraction column, W_2 , the quantity of the polar solvent in the first lean-solvent stream, subjected to cleansing by the first cleansing bed and optionally the second cleansing bed, W_1 , is relatively small. In certain specific embodiments, the first lean-solvent stream and the second lean-solvent stream are derived from a common lean-solvent stream, e.g., as two split streams from the common lean-solvent stream. The common lean-solvent stream can be a recycle solvent stream produced from, e.g., a distillation column separating a rich-solvent stream consisting essentially of the polar solvent and aromatic hydrocarbons. Although only a small fraction of the recycle lean-solvent stream is subjected to heavy components abatement using the cleansing station, the cumulative amount of heavy components removed and abated by the cleansing station can be significant over a prolonged operation campaign, capable of significantly increase the service life of the batch of the polar solvent circulating in the extraction system, with or without using additional means to further

purify the polar solvent in circulation such as sorbent beds, vacuum regeneration column, and steam stripping solvent regenerator.

[0051] In various embodiments of the process of the second aspect, the process may further comprise: (B-6) obtaining a bottoms stream from the extraction column, wherein the bottoms stream is rich in aromatic hydrocarbons and the polar solvent relative to the mixture feed; (B-7) separating at least a portion of the bottoms stream in a stripping column to obtain an aromatic hydrocarbons-rich stream depleted in the polar solvent relative to the bottoms stream, and a third lean-solvent stream depleted in aromatic hydrocarbons relative to the bottoms stream; and (B-8) deriving at least one of the first lean-solvent stream, the second lean-solvent stream, and the common lean-solvent stream from the third lean-solvent stream. In these embodiments, a circulation loop of the polar solvent exists in the overall process. As discussed above, step (B3) functions to purify at least a portion of the recycle lean-solvent stream to prolong the service life thereof in the overall process and system.

[0052] In certain specific embodiments comprising steps (B-12) to (B-14), the process may further comprise (B-9) deriving a fourth lean-solvent stream from the third lean-solvent stream; (B-10) regenerating the fourth lean-solvent stream in a steam stripping regeneration column and/or a vacuum regeneration column to obtain a regenerated lean-solvent stream comprising steam and a bottoms heavy stream; and (B-11) feeding the regenerated lean-solvent stream into one or more of: the stripping column, the extraction column, and the cleansing station as at least a portion of the first lean-solvent stream. In these embodiments, a regeneration column is utilized to further purify a lean-solvent stream, further prolonging the service life of the polar solvent in the process.

[0053] The activated carbon in the first cleansing bed and the ion exchange resin and/or alumina in the second cleansing bed may be provided with various adsorption capacity. Thus, after a certain period of online operation, the sorbents may become saturated with the contaminants adsorbed from the first lean-solvent stream. In such case, the sorbent(s) may be changed out and replaced with a fresh batch. Alternatively or additionally, the sorbents may be regenerated in-situ in the cleansing stations without being taken out. Alternatively, the changed out sorbents may be regenerated ex-situ to regain at least a portion of its adsorption capacity, and then reloaded into the cleaning stations where appropriate.

Detailed Description of the Processes/Systems Illustrated in FIG. 1

[0054] FIG. 1 schematically illustrates an exemplary extraction process/system 101 for separating aromatic hydrocarbons from a mixture feed comprising aromatic hydrocarbons and non-aromatic hydrocarbons using a sorbent bed 217 to cleanse a lean-solvent stream, according

to an embodiment of the various aspects of this disclosure. While the process and system illustrated in FIG. 1 and described below focus on an LLE process, one can adapt the process, equipment and system for ED processes and system as well. An exemplary solvent useful for the process of FIG. 1 is sulfolane. Another exemplary solvent is tetraethylene glycol.

[0055] As shown in this figure, a first lean-solvent stream 213 comprising primarily a polar solvent (e.g., sulfolane, tetraethylene glycol, or the like) and contaminants (e.g., heavy components), upon optional cooling via heat exchanger 215, is fed into a cleansing station 219 comprising a first cleansing bed 217 disposed therein. The first cleansing bed can preferably comprises an adsorbent such as activated carbon, an ion exchange resin, alumina, and the like, and combinations/mixtures thereof. On contacting bed 217, contaminants (e.g., heavy components) in stream 213 are selectively adsorbed by the sorbent material, and thus, stream 221 leaving the cleansing station 219 comprises contaminants at a reduced concentration compared to stream 213. Stream 221 can then be fed into the liquid-liquid extraction column 113, either separately (not shown) or optionally after combination with one or more other lean-solvent streams (e.g., streams 227, as shown) to form a join stream (stream 229, as shown). Additionally or alternatively, stream 221, or a portion thereof, may be fed into an extractive distillation column (not shown) to facilitate extractive distillation of a mixture feed comprising aromatic hydrocarbons and non-aromatic hydrocarbons. Additionally or alternatively (as shown), stream 221, or a portion thereof, may be fed into a stripping column (e.g., column 147, as shown) to facilitate separation. In various embodiments of the processes of this disclosure, by using a cleansing station having a cleansing bed therein, a lean-solvent stream containing contaminants (e.g., a recycle lean-solvent stream after a substantial operation period), or a portion thereof, can be conveniently purified under mild conditions with low energy consumption, low maintenance, low capital investment, and low operation costs.

[0056] We have also found that the solubility of the contaminants contained in the lean-solvent stream depends on the temperature of the stream. In general, the higher the temperature, the higher the solubility of the contaminants. When the concentration of the contaminants in the lean-solvent stream is higher than the saturation concentration (i.e., the maximum concentration at which the contaminants can be solubilized in the solvent to form a homogeneous solution), a phase separation occurs forming a heavy components phase (e.g., a hydrocarbon phase) rich in the contaminants and a solvent phase saturated with the heavy components. If allowed to settle to a certain extent, the heavy component phase accumulates on the top over the solvent phase due to density difference. Thus, in certain embodiments, where the lean-solvent stream may comprise the heavy components at above the saturation

concentration and a phase separation has occurred, one may allow the lean-solvent stream or a split stream thereof to settle in a vessel to a certain extent to form a hydrocarbon top layer and a bottoms solvent phase layer, decant the top layer, and returning the bottoms solvent phase layer to the LLE or ED column, after optionally being treated by using a sorbent bed such as an activated carbon bed, an alumina bed, an ion exchange resin bed, or any mixture or combination thereof, as described above and below suitable for treating a lean-solvent stream. In certain other embodiments, where the lean-solvent stream may comprise the contaminants approximate to (preferably below, but may be above) the saturation concentration and a phase separation has or has not occurred, one may cool the lean-solvent stream or a split stream thereof to a lower temperature having a contaminants saturation concentration lower than the actual concentration of the contaminants in the stream to induce (additional) phase separation, allow the cooled stream to settle in a vessel to a certain extent to form a hydrocarbon top layer and a bottoms solvent phase layer, decant the top layer, and returning the bottoms solvent phase layer to the LLE or ED column, after optionally being treated by using a sorbent bed such as an activated carbon bed, an alumina bed, an ion exchange resin bed, or any mixture or combination thereof, as described above and below suitable for treating a lean-solvent stream.

[0057] Preferably, the first lean-solvent stream 213 has a concentration of the contaminants, such as C10-C20 organic compounds (e.g., C14-C20 compounds, particularly C10-C20 hydrocarbons, and particularly C14-C20 hydrocarbons) no higher than, more preferably below, their saturation concentration in the solvent. In such case, no separate phase of the contaminants exists in the first lean-solvent stream.

[0058] As shown in FIG. 1, the first lean-solvent stream 213 and the second lean-solvent stream 145 (stream 144 upon cooling via heat exchanger 141) can be derived from a common lean-solvent stream 211. Stream 213 can be turned off from time to time in certain embodiments, especially where the common stream 211 has a high solvent purity indicated by a relatively low total concentration of the contaminants (e.g., a low total concentration of the heavy components therein, $c(\text{hcom-cs})$ wt%, based on the total weight of stream 211, e.g., where $c(\text{hcom-cs}) < 3$, or $c(\text{hcom-cs}) < 1$, or $c(\text{hcom-cs}) < 0.5$). In those cases purification of a portion of stream 211 by using the cleansing station 219 is not necessary. Thus, in an embodiment, one can monitor the concentration of the contaminants in the common lean-solvent stream 211, e.g., $c(\text{hcom-cs})$, and turn on the first lean-solvent stream 213 only when it reaches a threshold level, e.g., where $c(\text{hcom-cs}) \geq 0.5$, or $c(\text{hcom-cs}) \geq 1$, or $c(\text{hcom-cs}) \geq 3$, or even $c(\text{hcom-cs}) \geq 5$. Preferably $c(\text{hcom-cs}) \leq 20$, or $c(\text{hcom-cs}) \leq 18$, or $c(\text{hcom-cs}) \leq 16$, or $c(\text{hcom-cs}) \leq 15$, or $c(\text{hcom-cs}) \leq 12$. While it is possible to shut off the second lean-

solvent stream 145 completely so that the entirety of stream 211 becomes stream 213 and treated in the cleansing station 219, preferably stream 213 constitutes only a small portion of stream 211. Thus, in preferred embodiments, where in a given time period, the first lean-solvent stream 213 comprises the solvent at a total weight of W_1 , the second lean-solvent stream 145 comprises the solvent at a total weight of W_2 , streams 213 and 145 are regulated such that $0.5\% \leq W_1/(W_1+W_2) * 100\% \leq 10\%$, preferably $0.5\% \leq W_1/(W_1+W_2) * 100\% \leq 8\%$, preferably $0.5\% \leq W_1/(W_1+W_2) * 100\% \leq 5\%$, more preferably $1\% \leq W_1/(W_1+W_2) * 100\% \leq 5\%$, still more preferably $1\% \leq W_1/(W_1+W_2) * 100\% \leq 3\%$.

[0059] The overall process/system of FIG. 1 is now described as follows.

[0060] A mixture feed stream 103 comprising aromatic hydrocarbons and non-aromatic hydrocarbons, produced from, e.g., a naphtha reformat stream, a steam cracker naphtha stream, a biologically derived stream, a xylenes isomerization effluent stream, a transalkylation effluent stream, a toluene disproportionation effluent stream, or the like, or a mixture thereof, and recycle hydrocarbon streams 105, 107, and 109 derived from a common stream 111, also comprising aromatic hydrocarbons and non-aromatic hydrocarbons, are fed into a liquid-liquid distillation column 113 (alternatively, an extractive distillation column, not shown) at various locations on the column. A recycle lean-solvent stream 229 is fed into column 113 at a location above streams 103, 105, 107, and 109. Inside column 113, the polar solvent admixes with the hydrocarbons and descends to the bottom to produce a rich-solvent stream 139 rich in aromatic hydrocarbons and depleted in non-aromatic hydrocarbons relative to stream 103. From the top, a stream 115 rich in non-aromatic hydrocarbons and depleted in aromatic hydrocarbons relative to stream 103 is produced.

[0061] Stream 139, upon optionally being heated at heat exchanger 141 by a recycle lean-solvent stream 144, becomes stream 143 and can be fed into a stripping column 147 along with an optional steam stream 149 to produce an overhead stream 157 comprising steam and rich in non-aromatic hydrocarbons relative to stream 148 and a bottoms rich-solvent stream 151 rich in aromatic hydrocarbons. While stream 148 is shown as a single stream fed into column 147, it is also possible to split streams 148 into multiple streams, which are then fed into column 147 at differing locations, e.g., differing heights, on column 147. Stream 151 can be split into stream 153 for recycling to column 147 (upon heating by a heat exchanger) and stream 155 for feeding into solvent recovery column 161. In certain embodiments, it is also possible to feed another hydrocarbon stream comprising both aromatic hydrocarbons and non-aromatic hydrocarbons into column 147, e.g., a steam cracker naphtha stream. Such embodiments can

be particularly advantageous where the other hydrocarbon stream cannot be suitably fed into the extraction column 113 due to, e.g., hydraulic limitations.

[0062] Stream 115 from the top of column 113 can be supplied to a water wash column 121 along with a water-rich stream 171, from which a non-aromatic hydrocarbon stream 122 and an aqueous stream 125 are produced. Stream 122 can be split into a recycle stream 119 and a raffinate product stream 123. Stream 123, optionally after additional treatment such as drying and/or separation, can be used or made into various non-aromatic hydrocarbon products, e.g., mogas blending stocks. Stream 125, comprising hydrocarbons and water, can be then fed into a steam stripping column 133, along with a steam stream 203, optionally after combination with other aqueous streams such as stream 129 produced from a phase separator 127 to form a joint stream 131. We have found it is highly desirable to control the pH of these aqueous streams 125, 129, and 131 within the range from, e.g., 6 to 10, to reduce corrosion to the equipment and hence, improve process reliability. To that end, any of these streams (preferably stream 131) can be monitored for pH, and treated partly or entirely either continuously or intermittently (not shown) by, e.g., using an ion-exchange resin bed (preferably a strong base ion-exchange resin bed), an activated alumina bed, and/or injecting one or more bases such as amines and caustics (e.g., NaOH, KOH, and the like), and the like.

[0063] From the top of column 147, a hydrocarbon/steam mixture stream 157 and a bottoms stream 135 comprising solvent and water are produced. Stream 135, optionally after combination with stream 157 described above, can be condensed and then phase-separated in phase separator 127 to produce a hydrocarbon stream 111 and an aqueous stream 129. Stream 111 can then be recycled to column 113 as described above. Stream 129 can be combined with stream 125 to form stream 131 as described above. Stream 137 from the bottom of column 133 can then be fed into a steam generator 195, where it is heated by hot lean-solvent stream 189 to produce a steam stream 201 and a solvent-rich stream 199. Steam stream 201 can be split into streams 203 and 205. Stream 203 can be fed into steam stripping column 133 as described above.

[0064] Steam stream 205, along with an aromatic hydrocarbons-rich solvent stream 173, solvent-rich stream 196, and an optional lean-solvent stream 192 produced from a solvent regenerator 199, can then be fed into distillation column 161 (aka a solvent recovery column), to produce an aromatic hydrocarbon/steam mixture stream 163 from the top and a hot, lean-solvent stream 179 from the bottom. Stream 163, upon condensing (not shown) is then separated in phase separator 165 to obtain an aqueous stream 167 and an aromatic hydrocarbon stream 173. Stream 167 can be fed to water wash column 121 as described above. Similar to

streams 125, 129, and 131 described above, we have found that it is highly desirable to maintain the pH of stream 167 in the range of from, e.g., 8 to 10, in order to reduce equipment corrosion and enhance process reliability. Stream 167, or a portion thereof, may be likewise monitored for pH, and subjected to continuous or periodic treatment (not shown) to adjust its pH by, e.g., contacting an ion exchange resin bed, an activated alumina bed, and/or injecting one or more bases such as amines and caustics (e.g., NaOH, KOH, and the like) and the like. Stream 173 can be split into streams 177 recycled to column 161 and stream 175, which, upon optional additional processing such as drying, olefins removal, and distillation, can be used as is or made into various aromatic hydrocarbon products, e.g., benzene, toluene, benzene/toluene mixture, and the like. Stream 175 is also called an aromatics extract stream.

[0065] The hot lean-solvent stream 179 exiting the bottom of column 161 can be split into stream 181 for recycling to column 161 upon further heating via a heat exchanger, stream 185 for regeneration in the solvent regenerator 189 to produce a regenerated solvent stream 191, and stream 189 fed into steam generator 195 to heat stream 137 to produce steam stream 201 as described above. The solvent regenerator can be a steam regenerator, a deep vacuum regenerator, an activated carbon bed regenerator, an alumina bed regenerator, an activated carbon/alumina combination bed regenerator, and combinations thereof. Where a sorbent bed such as an activated carbon bed, an alumina bed, or an activated carbon/alumina combination bed(s) is used, the bed may be backwashed periodically by using an aromatic hydrocarbon such as toluene to remove adsorbed heavies. The cooled lean-solvent stream 197 exiting steam generator 195 can be filtered at filtration station 209 to remove certain contaminants such as particles. A magnetic filter may be used in filtration station 209 to remove any ferromagnetic particles entrained in stream 197. Preferably the filtration station 209 is capable of filtering solid particles having a diameter 1 micrometer or larger. A filtered stream 211 forms the common lean-solvent stream as described above. Additionally or alternatively (not shown), a filtration station differing from, similar to, or identical with filtration station 209 may be installed on the path of stream 227 after the heat exchanger 141, to supplement or replace station 209 as shown. Stream 211 can be split into the first lean-solvent stream 213 and the second lean-solvent stream 144 as described above. Stream 144, upon further cooling by the rich-solvent stream 139 produced at the bottom of column 113 at a heat exchanger 141 to form stream 145, can be fed into column 113 as described above. Solvent regenerator 189 can be, e.g., a steam stripping column, a vacuum regenerator column, a sorbent bed column containing a bed of a sorbent such as ion exchange resins, inorganic sorbent materials, and combinations thereof. As a result of the use of cleansing station 217 to de-contaminate at least a portion of

recycle lean-solvent stream 211 as described above, the solvent regenerator 189, can be de-commissioned or operated only intermittently if already existing, or not installed or installed with a reduced capacity in a grass-root plant, resulting in savings in equipment investment and/or operation costs.

[0066] After being placed into service for a period of time, an EDC or an LLE column may nonetheless foul due to various reasons and needs to shut down for cleaning. While mechanical cleaning has been used in the prior art for removing the foulant, it has been unexpectedly found that cleaning using a chemical can be effectively used with or without mechanical cleaning to restore capacity and the turnaround cycle. In a preferred embodiment, terpene can be used to clean foulant partly or completely from an extractive unit. A specific example of chemical cleaning useful for foulant cleaning in an extraction unit is the QuickTurn® technology available from Refined Technologies, Inc., The Woodlands, Texas, U.S.A. Alternatively or additionally, foulant can be dissolved using toluene, benzene, xylenes, or any mixtures thereof.

[0067] We have also found that O₂ ingress into the extraction system can be particularly detrimental to the degradation of the extraction solvent. To that end, it is highly desirable to install O₂ leak detection around the vacuum system to identify the ingress locations and to stop such O₂ ingress early and effectively.

[0068] Certain feed mixture intended to be fed into the extraction column, such as a continuous catalytic reformer (“CCR”) reformat stream, may comprise chlorine at an elevated concentration. While ion exchange resin beds, activated carbon beds, and activated alumina beds may be effective to remove at least a portion of organic chlorine from the solvent, it is highly desirable that before the feed mixture is fed into the extraction column, it is subjected to chlorine abatement by using, e.g., an organic chlorides liquid treater, in order to reduce the chlorides ingress into the extraction unit.

[0069] While the above description focuses on using either an LLE or an ED column in an extraction unit, it is also possible, and in certain embodiments desirable, to use a combination of an LLE unit and an ED unit. For example, in an extraction unit, an LLE column and an ED column may be operated in parallel, with the hydrocarbon feed streams having high aromatic hydrocarbon concentrations fed into the ED column, and the hydrocarbon feed streams having relatively low aromatic hydrocarbon concentrations fed into the LLE column, to achieve an optimal energy efficiency in the extraction separation process.

[0070] Under certain circumstances, e.g., where the supply of the feed stream to the EDC or LLE column is interrupted for some reason, the normal operation of the extraction unit may have to be paused. In such cases, we have found it to be particularly beneficial to maintain the

unit at an elevated temperature, e.g., in proximity to the normal operating temperature thereof, instead of cooling it down to ambient temperature. Maintaining an elevated temperature can prevent the precipitation of high-molecular-weight foulants in the extraction column onto internal surfaces in the column, e.g., surfaces of the trays, causing irreversible capacity and/or selectivity reduction even if the temperature in the column is raised again later. When feed supply is interrupted, one may recycle the extract stream and/or the raffinate stream into the extraction column to form a recycle loop, thereby maintaining the flow of streams in the extraction unit mimicking normal operating conditions.

Detailed Description of the Benzene-Recovery Processes/Systems Illustrated in FIG. 2

[0071] FIG. 2 schematically illustrates an exemplary process/system useful for separating a benzene-containing aromatics extract stream to produce a benzene product stream, which may be called a “recovery section.” The aromatics extract stream can be produced by a process of the first and/or second aspect of this disclosure. As shown in FIG. 2, stream 502, which can comprise, consist essentially of, or consist of, stream 175 produced from the process/system of FIG. 1, rich in aromatic hydrocarbons such as benzene, toluene, C8 aromatic hydrocarbons, and C9 aromatic hydrocarbons, is heated by a series of heat exchangers 503, 505, and 507 to form a stream having an elevated temperature, e.g., from 177 to 218 °C (350 to 425 °F) (preferably from 190 to 204 °C (375 to 400 °F)). Depending on the source of the hydrocarbon mixture feed supplied to the extraction unit, the aromatics extract stream 502, and hence stream 509 may comprise olefinic hydrocarbons, such as vinylbenzene, at non-negligible concentrations. It would be highly desirable to remove the olefinic hydrocarbons from the aromatics extract stream before distillation to prevent them from contaminating downstream aromatic hydrocarbon streams. To that end, as shown in FIG. 2, stream 509 is allowed to pass through reactors 511 and 513 connected in series, in each of which one or more fixed bed(s) of treating catalyst is placed. On contacting the treating catalyst, the olefinic hydrocarbons are converted into heavier molecules, which can be conveniently separated from desirable molecules in subsequent distillation processes. Exemplary treating catalyst can include one or more beds of clay(s) and/or the Olgone® material available from ExxonMobil Chemical Company having an address at 4500 Bayway Drive, Baytown, Texas 77545, U.S.A.

[0072] Stream 515 exiting reactor 513, upon being cooled at heat exchanger 503 by stream 502, is then fed into a benzene distillation column 519, from which an overhead stream 521, an upper-middle stream 533, and a bottoms stream 541 are produced. Stream 521, comprising water, benzene, and optionally light hydrocarbons, is then cooled down and condensed by, e.g., a fin-fan 523 to obtain a liquid mixture, which is then fed into a separation drum 525. A liquid,

aqueous stream 527 rich in water and comprising benzene separated from drum 525 can be sent to a waste water treatment station (not shown). An oil stream 528 from drum 525 can be recycled to column 519 as a reflux stream in its entirety (not shown) or partly as stream 529 (as shown). A split stream 531 from stream 528, particularly if containing relatively high concentration of light non-aromatic hydrocarbons, can be fed into steam stripping column 147 as at least a portion of stream 149 as shown in FIG. 1. Stream 533 can be drawn from a location of column 519 such that it comprises benzene at a high purity meeting various product specification for its intended use. Stream 533, upon being cooled down via heat exchanger 535, becomes a benzene product stream 537 at a lower temperature, e.g., ambient temperature, which can be delivered to storage tank 539. The bottoms stream 541, comprising C7+ aromatic hydrocarbons, can be split into streams 542 and 543. Stream 542 can be heated by a reboiler heat exchanger 545 to become stream 547 having a higher temperature, which is then recycled into column 519. Stream 543, upon being cooled down via heat exchanger 549, becomes a stream 551 having a lower temperature, e.g., ambient temperature, which can be delivered to storage tank 553 (as shown), or fed into a further distillation column (e.g., a toluene column) from which one or more additional product streams, e.g., a toluene stream, a C8 aromatic hydrocarbon stream, a C9+ hydrocarbon stream, can be produced. The various distillation columns including but not limited to the benzene column 519 and the toluene column may be heat integrated with the various equipment in the extraction unit, such as the unit shown in FIG. 1. For example, where an EDC is used in the extraction unit and a toluene column is included in the aromatics recovery section, heat integration between the EDC and the toluene column can be conveniently utilized to achieve a high energy efficiency.

EXAMPLES

Example 1

[0073] Into a test tube 10 grams of fresh granular activated carbon was placed. A quantity of a contaminated sulfolane mixture taken from an aromatics hydrocarbon extraction unit, comprising 92.82 wt% (“Starting Sulfolane Concentration”) of sulfolane and balance heavy hydrocarbons, primarily those having ≥ 10 carbon atoms per molecule, at room temperature, was then put into the test tube to soak the activated carbon. The test tube was then sealed with a lid and maintained at room temperature for 24 hours. The lid was then taken off and a sample of the liquid in the test tube was taken to measure concentration of sulfolane therein (“End Sulfolane Concentration”). The experiment was conducted for five runs with different quantities of the contaminated sulfolane mixture. Data are presented in TABLE I below:

TABLE I

<u>Run No.</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
Activated Carbon (grams)	10	10	10	10	10
Contaminated Solvent Mixture (grams)	30.30	40.00	50.00	71.43	200.00
Starting Sulfolane Concentration (wt%)	92.82	92.82	92.82	92.82	92.82
End Sulfolane Concentration (wt%)	99.55	99.11	98.56	97.24	94.56

[0074] This lab test clearly demonstrated that activated carbon can be used to cleanse a contaminated sulfolane mixture. Apparently a portion of the heavy hydrocarbons contained in the contaminated sulfolane mixture was adsorbed and removed from the sulfolane mixture in all Run Nos. 1 to 5 above. In Run No. 1, at the highest carbon/(contaminated solvent mixture) weight ratio of about 1:3, essentially all of the contaminants were cleansed, leaving high-purity sulfolane behind. As the ratio decreased, residual contaminants increased after the 24-hour treatment. However, even in Run No. 5, at the lowest carbon/(contaminated solvent mixture) weight ratio of 1:20, still a significant amount of contaminants was cleansed of the solvent mixture.

Example 2

[0075] In this Example 2, four runs of tests were performed to demonstrate the efficacy of an activated carbon fixed bed in cleansing a contaminated sulfolane sample. In each run, a vertical glass tube (a burette) having an approximately 1 inch (2.54 cm) inner diameter having an upper opening and a lower opening controlled by a valve that can be turned on to allow liquid in the tube to drain downwards was used. With the valve turned off, to the glass tube was first placed a layer of quartz particles. Then a given weight of dry activated carbon particles ("Carbon Weight") was packed into the glass tube above the quartz layer. Afterwards a given weight of pure sulfolane ("Soak Sulfolane Weight") was added into tube to soak the activated carbon particles for a given period of time ("Soak Time") in order to completely wet the carbon particles. In each run, a given volume of a contaminated sulfolane sample having a pre-determined sulfolane concentration of $c(s)$ wt%, expressed as weight percentage of sulfolane based on the total weight of the contaminated sulfolane sample, was subsequently added into the tube over a period of time. The valve was then turned on to allow the liquid to drain out of the tube from the lower opening. The effluent draining out was collected into multiple effluent samples, each corresponding to a substantially equal draining time period. Each effluent sample was measured for sulfolane concentration using gas chromatography ("GC"). The ratio of the sulfolane concentration of each effluent sample to the sulfolane concentration in the contaminated sulfolane sample was calculated as the impurity profile of the effluent sample. The total time period from the start to the completion of effluent draining

was recorded as treatment time (“Treatment Time”) for the run. The effluent samples from a given run were combined to form a total effluent mixture, the sulfolane concentration of which was measured by GC. A given volume of the total effluent mixture was then used as the contaminated sulfolane sample for the next test run. Data of each run are given in TABLE II below. In FIG. 3, a graph showing the impurity profile of each effluent sample in each run as a function of draining time is presented.

TABLE II

Run No.	Carbon Weight (g)	Soak Sulfolane Weight (g)	Soak Time (minutes)	Contaminated Sulfolane Used		Treatment Time (minutes)	Carbon Usage (g/ml)	Effluent Samples Collected
				Volume (ml)	Sulfolane Concentration (wt%)			
1	40	80	30	450	92.85	34.65	0.089	6
2	30	60	10	215	93.63	26.62	0.14	10
3	20	40	10	185	94.09	25.42	0.11	9
4	15	30	10	185	94.66	60.9	0.081	9

[0076] As can be seen from TABLE I and FIG. 3, at various loading of the activated carbon, effective contaminant removal can be achieved.

[0077] This disclosure can include one or more of the following non-limiting aspects and/or embodiments.

Listing of Embodiments

[0078] A1. A process for extracting aromatic hydrocarbons from a mixture feed comprising aromatic hydrocarbons and non-aromatic hydrocarbons, the process comprising:

(A-1) feeding the mixture feed into an extraction column;

(A-2) providing a first lean-solvent stream comprising a polar solvent at a concentration of $c(ps)$ wt%, and heavy components at a total concentration of $c(hcom)$ wt%, based on the total weight of the lean-solvent stream, where $75 \leq c(ps) \leq 99.99$;

(A-3) obtaining a cleansed first lean-solvent stream by (A3-a) contacting the first lean-solvent stream with a first cleansing bed comprising activated carbon; and

(A-4) feeding at least a portion of the cleansed first lean-solvent stream into the extraction column.

[0079] A1a. The process of A1, wherein $c(hcom)$ wt% $\leq c(sat)$ wt%, where $c(sat)$ wt% is the saturation concentration of the heavy components in the polar solvent at the temperature of the first lean-solvent stream provided in step (A-2), expressed as weight percentage of the heavy components on the basis of the total weight of the heavy components and the polar solvent;

preferably $c(\text{hcom}) \text{ wt\%} < c(\text{sat}) \text{ wt\%}$; preferably $c(\text{hcom}) \text{ wt\%} \leq 0.8 c(\text{sat}) \text{ wt\%}$; preferably $c(\text{hcom}) \text{ wt\%} \leq 0.6 c(\text{sat}) \text{ wt\%}$; preferably $c(\text{hcom}) \text{ wt\%} \leq 0.5 c(\text{sat}) \text{ wt\%}$.

[0080] A2. The process of A1 or A1a, wherein step (A-3) further comprises (A-3b) contacting the first lean-solvent stream with a second cleansing bed comprising an ion exchange resin and/or alumina.

[0081] A3. The process of A2, wherein in step (A-3b), the second cleansing bed comprises a basic ion exchange resin.

[0082] A4. The process of any of A1 to A3, wherein step (A-3a) precedes step (A-3b).

[0083] A4a. The process of any of A1 to A3, wherein step (A-3b) precedes step (A-3a).

[0084] A5. The process of any of A1 to A4a, wherein $0.01 \leq c(\text{hcom}) \leq 20$; preferably $0.1 \leq c(\text{hcom}) \leq 15$; preferably $0.5 \leq c(\text{hcom}) \leq 10$; preferably $1 \leq c(\text{hcom}) \leq 5$.

[0085] A6. The process of any of A1 to A5, wherein the activated carbon has a specific surface area from 1,000 to 1,500 m²/g, as measured using BET.

[0086] A7. The process of any of A1 to A6, wherein the first cleansing bed and the second cleansing bed are disposed in separate vessels.

[0087] A8. The process of any of A1 to A6, wherein the first cleansing bed and the second cleansing bed are disposed in a common vessel.

[0088] A9. The process of any of A1 to A8, wherein:
the extraction column is an extractive distillation column.

[0089] A10. The process of any of A1 to A8, wherein:
the extraction column is a liquid-liquid extraction column.

[0090] A11. The process of any of A1 to A10, wherein:
the polar solvent is selected from tetraethylene glycol, triethylene glycol, diethylene glycol, ethylene glycol, methoxy triglycol ether, diglycolamine, dipropylene glycol, N-formyl morpholine, N-methyl pyrrolidone, 2,3,4,5-tetrahydrothiophene-1,1-dioxide ("sulfolane"), 3-methylsulfolane and dimethyl sulfoxide, tetramethylenesulfone, mixtures thereof, and/or admixtures with water thereof.

[0091] A12. The process of any of A1 to A7, wherein:
the first lean-solvent stream has a temperature in a range from 25 to 80 °C when contacting the first cleansing bed; and/or

the first lean-solvent stream has a temperature in a range from 25 to 80 °C when contacting the second cleansing bed.

[0092] A13. The process of any of A1 to A12, further comprising:

(A-5) feeding a second lean-solvent stream comprising the polar solvent into the extraction column.

[0093] A14. The process of A13, wherein in a given time period, the first lean-solvent stream comprises the polar solvent at a total weight of W1, the second lean-solvent stream comprises the polar solvent at a total weight of W2, and $0.5\% \leq W1/(W1+W2) * 100\% \leq 10\%$.

[0094] A15. The process of A14, wherein $0.5\% \leq W1/(W1+W2) * 100\% \leq 8\%$, preferably $0.5\% \leq W1/(W1+W2) * 100\% \leq 5\%$, more preferably $1\% \leq W1/(W1+W2) * 100\% \leq 5\%$, still more preferably $1\% \leq W1/(W1+W2) * 100\% \leq 3\%$.

[0095] A16. The process of any of A13 to A15, wherein the first lean-solvent stream and the second lean-solvent stream are derived from a common lean-solvent stream.

[0096] A17. The process of any of A1 to A16, further comprising:

(A-6) obtaining a bottoms stream from the extraction column, wherein the bottoms stream is rich in aromatic hydrocarbons and the polar solvent relative to the mixture feed;

(A-7) separating at least a portion of the bottoms stream in a solvent recovery column to obtain an upper stream rich in aromatic hydrocarbons and depleted in the polar solvent relative to the bottoms stream, and a third lean-solvent lower stream depleted in aromatic hydrocarbons relative to the bottoms stream; and

(A-8) deriving at least one of the first lean-solvent stream, the second lean-solvent stream, and the common lean-solvent stream from the third lean-solvent lower stream.

[0097] A18. The process of A17, further comprising:

(A-9) deriving a fourth lean-solvent stream from the third lean-solvent stream;

(A-10) regenerating the fourth lean-solvent stream in a steam stripping regenerator and/or a vacuum regenerator to obtain a regenerated lean-solvent stream comprising steam and a bottoms heavy stream; and

(A-11) feeding the regenerated lean-solvent stream into one or both of the solvent recovery column and the extraction column.

[0098] A19. The process of any of A1 to A17, wherein the extraction column is a liquid/liquid extraction column, and the process does not include regenerating a portion of the polar solvent using a steam regenerator or a vacuum regenerator.

[0099] A20. The process of any of A1 to A19, further comprising:

(A-12) interrupting or reducing supply of the mixture feed fed into the extraction column; and

(A-13) maintaining a temperature in the extraction column in proximity to temperature thereof before the interrupting or reducing supply of the mixture feed in step (A-12).

[0100] B1. A process for extracting aromatic hydrocarbons from a mixture feed comprising aromatic hydrocarbons and non-aromatic hydrocarbons, the process comprising:

(B-1) feeding the mixture feed into an extractive distillation column;

(B-2) providing a first lean-solvent stream comprising a polar solvent at a concentration of $c(\text{ps})$ wt%, and heavy components at a total concentration of $c(\text{hcom})$ wt%, based on the total weight of the lean-solvent stream, where $75 \leq c(\text{ps}) \leq 99.99$;

(B-3) obtaining a cleansed first lean-solvent stream by (B3-a) contacting the first lean-solvent stream with an primary cleansing bed comprising an ion exchange resin; and

(B-4) feeding at least a portion of the cleansed first lean-solvent stream into the extraction column.

[0101] B1a. The process of B1, wherein $c(\text{hcom}) \text{ wt\%} \leq c(\text{sat}) \text{ wt\%}$, where $c(\text{sat}) \text{ wt\%}$ is the saturation concentration of the heavy components in the polar solvent at the temperature of the first lean-solvent stream provided in step (B-2), expressed as weight percentage of the heavy components on the basis of the total weight of the heavy components and the polar solvent; preferably $c(\text{hcom}) \text{ wt\%} < c(\text{sat}) \text{ wt\%}$; preferably $c(\text{hcom}) \text{ wt\%} \leq 0.8 c(\text{sat}) \text{ wt\%}$; preferably $c(\text{hcom}) \text{ wt\%} \leq 0.6 c(\text{sat}) \text{ wt\%}$; preferably $c(\text{hcom}) \text{ wt\%} \leq 0.5 c(\text{sat}) \text{ wt\%}$.

[0102] B2. The process of B1 or B1a, wherein step (B-3) further comprises (B-3b) contacting the first lean-solvent stream with a secondary cleansing bed comprising activated carbon.

[0103] B3. The process of B2, wherein in step (B-3b), the primary cleansing bed comprises a basic ion exchange resin.

[0104] B4. The process of any of B1 to B3, wherein step (B-3a) precedes step (B-3b).

[0105] B4a. The process of any of B1 to B3, wherein step (B-3b) precedes step (B-3a).

[0106] B5. The process of any of B1 to B4, wherein $0.01 \leq c(\text{hcom}) \leq 20$; preferably $0.1 \leq c(\text{hcom}) \leq 15$; preferably $0.5 \leq c(\text{hcom}) \leq 10$; preferably $1 \leq c(\text{hcom}) \leq 5$.

[0107] B6. The process of any of B1 to B5, wherein the activated carbon has a specific surface area from 1,000 to 1,500 m²/g, as measured using BET.

[0108] B7. The process of any of B1 to B6, wherein the primary cleansing bed and the secondary cleansing bed are disposed in separate vessels.

[0109] B8. The process of any of B1 to B6, wherein the primary cleansing bed and the secondary cleansing bed are disposed in a common vessel.

[0110] B9. The process of any of B1 to B8, wherein:

the polar solvent is selected from tetraethylene glycol, triethylene glycol, diethylene glycol, ethylene glycol, methoxy triglycol ether, diglycolamine, dipropylene glycol, N-formyl morpholine, N-methyl pyrrolidone, 2,3,4,5-tetrahydrothiophene-1,1-dioxide ("sulfolane"), 3-

methysulfolane and dimethyl sulfoxide, tetramethylenesulfone, mixtures thereof, and/or admixtures with water thereof.

[0111] B10. The process of any of B1 to B9, wherein:

the first lean-solvent stream has a temperature in a range from 25 to 80 °C (preferably 25 to 65 °C) when contacting the primary cleansing bed; and/or

the first lean-solvent stream has a temperature in a range from 25 to 80 °C (preferably 25 to 65 °C) when contacting the secondary cleansing bed.

[0112] B11. The process of any of B1 to B10, further comprising:

(B-5) feeding a second lean-solvent stream comprising the polar solvent into the extraction column.

[0113] B12. The process of B11, wherein in a given time period, the first lean-solvent stream comprises the polar solvent at a total weight of W1, the second lean-solvent stream comprises the polar solvent at a total weight of W2, and $0.5\% \leq W1/(W1+W2) * 100\% \leq 10\%$.

[0114] B13. The process of B12, wherein $0.5\% \leq W1/(W1+W2) * 100\% \leq 8\%$, preferably $0.5\% \leq W1/(W1+W2) * 100\% \leq 5\%$, more preferably $1\% \leq W1/(W1+W2) * 100\% \leq 5\%$, still more preferably $1\% \leq W1/(W1+W2) * 100\% \leq 3\%$.

[0115] B14. The process of any of B11 to B13, wherein the first lean-solvent stream and the second lean-solvent stream are derived from a common lean-solvent stream.

[0116] B15. The process of any of B1 to B14, further comprising:

(B-6) obtaining a bottoms stream from the extraction column, wherein the bottoms stream is rich in aromatic hydrocarbons and the polar solvent relative to the mixture feed;

(B-7) separating at least a portion of the bottoms stream in a solvent recovery column to obtain an upper stream rich in aromatic hydrocarbons and depleted in the polar solvent relative to the bottoms stream, and a third lean-solvent lower stream depleted in aromatic hydrocarbons relative to the bottoms stream; and

(B-8) deriving at least one of the first lean-solvent stream, the second lean-solvent stream, and the common lean-solvent stream from the third lean-solvent stream.

[0117] B16. The process of B15, further comprising:

(B-9) deriving a fourth lean-solvent stream from the third lean-solvent stream;

(B-10) regenerating the fourth lean-solvent stream in a steam stripping regenerator and/or a vacuum regenerator to obtain a regenerated lean-solvent stream comprising steam and a bottoms heavy stream; and

(B-11) feeding the regenerated lean-solvent stream into one or both of the solvent recovery column and the extraction column.

[0118] B17. The process of any of B1 to B15, wherein the process does not include regenerating a portion of the polar solvent using a steam regenerator or a vacuum regenerator.

[0119] B18. The process of any of B1 to B17, further comprising:

(B-12) interrupting or reducing supply of the mixture feed fed into the extraction column; and

(B-13) maintaining a temperature in the extraction column in proximity to temperature thereof before the interrupting or reducing supply of the mixture feed in step (A-12).

CLAIMS

What is claimed is:

1. A process for extracting aromatic hydrocarbons from a mixture feed comprising aromatic hydrocarbons and non-aromatic hydrocarbons, the process comprising:
 - (A-1) feeding the mixture feed into an extraction column;
 - (A-2) providing a first lean-solvent stream comprising a polar solvent at a concentration of $c(\text{ps})$ wt%, and heavy components at a total concentration of $c(\text{hcom})$ wt%, based on the total weight of the lean-solvent stream, where $75 \leq c(\text{ps}) \leq 99.99$;
 - (A-3) obtaining a cleansed first lean-solvent stream by (A3-a) contacting the first lean-solvent stream with a first cleansing bed comprising activated carbon; and
 - (A-4) feeding at least a portion of the cleansed first lean-solvent stream into the extraction column.
2. The process of claim 1, wherein $c(\text{hcom}) \text{ wt\%} \leq c(\text{sat}) \text{ wt\%}$, where $c(\text{sat}) \text{ wt\%}$ is the saturation concentration of the heavy components in the polar solvent at the temperature of the first lean-solvent stream provided in step (A-2), expressed as weight percentage of the heavy components on the basis of the total weight of the heavy components and the polar solvent; preferably $c(\text{hcom}) \text{ wt\%} < c(\text{sat}) \text{ wt\%}$; preferably $c(\text{hcom}) \text{ wt\%} \leq 0.8 c(\text{sat}) \text{ wt\%}$; preferably $c(\text{hcom}) \text{ wt\%} \leq 0.6 c(\text{sat}) \text{ wt\%}$; preferably $c(\text{hcom}) \text{ wt\%} \leq 0.5 c(\text{sat}) \text{ wt\%}$.
3. The process of claim 1 or claim 2, wherein step (A-3) further comprises (A-3b) contacting the first lean-solvent stream with a second cleansing bed comprising an ion exchange resin and/or alumina.
4. The process of any of the preceding claims, wherein $0.01 \leq c(\text{hcom}) \leq 20$; preferably $0.1 \leq c(\text{hcom}) \leq 15$; preferably $0.5 \leq c(\text{hcom}) \leq 10$; preferably $1 \leq c(\text{hcom}) \leq 5$.
5. The process of any of the preceding claims, wherein the activated carbon has a specific surface area from 1,000 to 1,500 m²/g, as measured using BET.
6. The process of any of the preceding claims, wherein:

the extraction column is an extractive distillation column or a liquid-liquid extraction column.
7. The process of any of the preceding claims, wherein:

the polar solvent is selected from tetraethylene glycol, triethylene glycol, diethylene glycol, ethylene glycol, methoxy triglycol ether, diglycolamine, dipropylene glycol, N-formyl morpholine, N-methyl pyrrolidone, 2,3,4,5-tetrahydrothiophene-1,1-dioxide ("sulfolane"), 3-methylsulfolane and dimethyl sulfoxide, tetramethylenesulfone, mixtures thereof, and/or admixtures with water thereof.

8. The process of any of the preceding claims, wherein:
 - the first lean-solvent stream has a temperature in a range from 25 to 80 °C when contacting the first cleansing bed; and/or
 - the first lean-solvent stream has a temperature in a range from 25 to 80 °C when contacting the second cleansing bed.
9. The process of any of the preceding claims, further comprising:
 - (A-5) feeding a second lean-solvent stream comprising the polar solvent into the extraction column;
 - wherein in a given time period, the first lean-solvent stream comprises the polar solvent at a total weight of W1, the second lean-solvent stream comprises the polar solvent at a total weight of W2, and $0.5\% \leq W1/(W1+W2) * 100\% \leq 10\%$; preferably $0.5\% \leq W1/(W1+W2) * 100\% \leq 8\%$; preferably $0.5\% \leq W1/(W1+W2) * 100\% \leq 5\%$; more preferably $1\% \leq W1/(W1+W2) * 100\% \leq 5\%$; still more preferably $1\% \leq W1/(W1+W2) * 100\% \leq 3\%$.
10. The process of claim 9, wherein the first lean-solvent stream and the second lean-solvent stream are derived from a common lean-solvent stream.
11. The process of any of the preceding claims, further comprising:
 - (A-6) obtaining a bottoms stream from the extraction column, wherein the bottoms stream is rich in aromatic hydrocarbons and the polar solvent relative to the mixture feed;
 - (A-7) separating at least a portion of the bottoms stream in a solvent recovery column to obtain an upper stream rich in aromatic hydrocarbons and depleted in the polar solvent relative to the bottoms stream, and a third lean-solvent lower stream depleted in aromatic hydrocarbons relative to the bottoms stream; and
 - (A-8) deriving at least one of the first lean-solvent stream, the second lean-solvent stream, and the common lean-solvent stream from the third lean-solvent lower stream.
12. The process of claim 11, further comprising:
 - (A-9) deriving a fourth lean-solvent stream from the third lean-solvent stream;
 - (A-10) regenerating the fourth lean-solvent stream in a steam stripping regenerator and/or a vacuum regenerator to obtain a regenerated lean-solvent stream comprising steam and a bottoms heavy stream; and
 - (A-11) feeding the regenerated lean-solvent stream into one or both of the solvent recovery column and the extraction column.
13. The process of any of the preceding claims, wherein the extraction column is a liquid/liquid extraction column, and the process does not include regenerating a portion of the polar solvent using a steam regenerator or a vacuum regenerator.

14. The process of any of the preceding claims, further comprising:
(A-12) interrupting or reducing supply of the mixture feed fed into the extraction column; and
(A-13) maintaining a temperature in the extraction column in proximity to temperature thereof before the interrupting or reducing supply of the mixture feed in step (A-12).
15. A process for extracting aromatic hydrocarbons from a mixture feed comprising aromatic hydrocarbons and non-aromatic hydrocarbons, the process comprising:
(B-1) feeding the mixture feed into an extractive distillation column;
(B-2) providing a first lean-solvent stream comprising a polar solvent at a concentration of $c(\text{ps})$ wt%, and heavy components at a total concentration of $c(\text{hcom})$ wt%, based on the total weight of the lean-solvent stream, where $75 \leq c(\text{ps}) \leq 99.99$;
(B-3) obtaining a cleansed first lean-solvent stream by (B3-a) contacting the first lean-solvent stream with an primary cleansing bed comprising an ion exchange resin; and
(B-4) feeding at least a portion of the cleansed first lean-solvent stream into the extraction column.
16. The process of claim 15, wherein $c(\text{hcom}) \text{ wt}\% \leq c(\text{sat}) \text{ wt}\%$, where $c(\text{sat}) \text{ wt}\%$ is the saturation concentration of the heavy components in the polar solvent at the temperature of the first lean-solvent stream provided in step (B-2), expressed as weight percentage of the heavy components on the basis of the total weight of the heavy components and the polar solvent; preferably $c(\text{hcom}) \text{ wt}\% < c(\text{sat}) \text{ wt}\%$; preferably $c(\text{hcom}) \text{ wt}\% \leq 0.8 c(\text{sat}) \text{ wt}\%$; preferably $c(\text{hcom}) \text{ wt}\% \leq 0.6 c(\text{sat}) \text{ wt}\%$; preferably $c(\text{hcom}) \text{ wt}\% \leq 0.5 c(\text{sat}) \text{ wt}\%$.
17. The process of claim 15 or claim 16, wherein step (B-3) further comprises (B-3b) contacting the first lean-solvent stream with a secondary cleansing bed comprising activated carbon.
18. The process of claim 17, wherein in step (B-3b), the primary cleansing bed comprises a basic ion exchange resin.
19. The process of any of claims 15 to 18, wherein $0.01 \leq c(\text{hcom}) \leq 20$; preferably $0.1 \leq c(\text{hcom}) \leq 15$; preferably $0.5 \leq c(\text{hcom}) \leq 10$; preferably $1 \leq c(\text{hcom}) \leq 5$.
20. The process of any of claims 15 to 19, wherein the activated carbon has a specific surface area from 1,000 to 1,500 m²/g, as measured using BET.
21. The process of any of claims 15 to 20, wherein:
the first lean-solvent stream has a temperature in a range from 25 to 80 °C (preferably 25 to 65 °C) when contacting the primary cleansing bed; and/or

the first lean-solvent stream has a temperature in a range from 25 to 80 °C (preferably 25 to 65 °C) when contacting the secondary cleansing bed.

22. The process of any of claims 15 to 21, further comprising:

(B-5) feeding a second lean-solvent stream comprising the polar solvent into the extraction column; wherein in a given time period, the first lean-solvent stream comprises the polar solvent at a total weight of W1, the second lean-solvent stream comprises the polar solvent at a total weight of W2, and $0.5\% \leq W1/(W1+W2) * 100\% \leq 10\%$; preferably $0.5\% \leq W1/(W1+W2) * 100\% \leq 8\%$, preferably $0.5\% \leq W1/(W1+W2) * 100\% \leq 5\%$, more preferably $1\% \leq W1/(W1+W2) * 100\% \leq 5\%$, still more preferably $1\% \leq W1/(W1+W2) * 100\% \leq 3\%$.

23. The process of any of claims 15 to 22, further comprising:

(B-6) obtaining a bottoms stream from the extraction column, wherein the bottoms stream is rich in aromatic hydrocarbons and the polar solvent relative to the mixture feed;

(B-7) separating at least a portion of the bottoms stream in a solvent recovery column to obtain an upper stream rich in aromatic hydrocarbons and depleted in the polar solvent relative to the bottoms stream, and a third lean-solvent lower stream depleted in aromatic hydrocarbons relative to the bottoms stream; and

(B-8) deriving at least one of the first lean-solvent stream, the second lean-solvent stream, and the common lean-solvent stream from the third lean-solvent stream.

24. The process of claim 23, further comprising:

(B-9) deriving a fourth lean-solvent stream from the third lean-solvent stream;

(B-10) regenerating the fourth lean-solvent stream in a steam stripping regenerator and/or a vacuum regenerator to obtain a regenerated lean-solvent stream comprising steam and a bottoms heavy stream; and

(B-11) feeding the regenerated lean-solvent stream into one or both of the solvent recovery column and the extraction column.

25. The process of any of claims 15 to 24, further comprising:

(B-12) interrupting or reducing supply of the mixture feed fed into the extraction column; and

(B-13) maintaining a temperature in the extraction column in proximity to temperature thereof before the interrupting or reducing supply of the mixture feed in step (A-12).