

MERCURY AND SILICON REMOVAL FROM PLASTIC-DERIVED PYROLYSIS OIL

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CROSS-REFERENCE TO RELATED APPLICATIONS

- 5 [0001] This application claims the priority benefit of USSN 62/925,450, filed October 24, 2019, which is incorporated herein by reference.

FIELD

[0002] The present disclosure relates to methods and systems for removing contaminants from plastic-derived pyrolysis oil.

10 **BACKGROUND**

[0003] Recycling of plastic waste is a subject of increasing importance. Currently, only about 9% of plastics used around the world are recycled. Primarily, plastic waste ends up in landfills.

- 15 [0004] One proposed method of reusing plastics is pyrolyzing plastic waste to reduce the carbon number. The resultant product can be distilled where a pyrolyzed oil fraction can be used as feedstock for stream cracking, which further reduces the carbon number. The final result is a low carbon number product that can be used as a feedstock in various syntheses including polymers synthesis.

- 20 [0005] Plastic waste procured from various sources (and pyrolysis oils produced therefrom), however, are known to have various non-hydrocarbon contaminants such as metals and metalloids. See e.g., Okuwaki, A. et al. (2006) "The Liquefaction of Plastic Containers and Packaging in Japan"; *Feedstock Recycling and Pyrolysis of Waste Plastics: Converting Waste Plastics into Diesel and Other Fuels*, Part VI, Chap. 26, Asian Developments, 45 pgs.; Canopoli, L. et al. (2018) "Physico-Chemical Properties of Excavated Plastic from Landfill Mining and Current Recycling Routes", *Waste Management*, v.76, pp. 55–67; Eriksen, M.K. et al. (2018) "Contamination in Plastic Recycling: Influence of Metals on the Quality of Reprocessed Plastic"; *Waste Management*, v.79, pp. 595–606. Some of these contaminants, particularly silicon and mercury, are undesirable for certain chemical upgrading processes even in relatively low concentrations (e.g., concentrations greater than 5 wppm for silicon and
- 25 concentrations greater than 1 wppb for mercury). For example, silicon and mercury can deactivate catalysts in the downstream synthesis processes. This can result in unreliable process operation and/or off-specification products. Further, mercury, in addition to environmental emission issues, can weaken aluminum welds in downstream recovery and separation units, which poses process safety concerns.
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SUMMARY OF THE INVENTION

[0006] The present disclosure relates to methods and systems for removing silicon and/or mercury contaminants from plastic-derived pyrolysis oil.

[0007] A first nonlimiting example method of the present disclosure comprises: removing
5 silicon from a plastic-derived pyrolysis oil to yield a purified plastic-derived pyrolysis oil comprising 5 wppm or less of silicon; and steam cracking the plastic-derived pyrolysis oil in the presence of steam to produce a product.

[0008] A second nonlimiting example method of the present disclosure comprises: removing mercury from a plastic-derived pyrolysis oil to yield a purified plastic-derived
10 pyrolysis oil comprising 1 wppb or less of mercury; and steam cracking the plastic-derived pyrolysis oil in the presence of a steam to produce a product.

[0009] A third nonlimiting example method of the present disclosure comprises: removing silicon and mercury from a plastic-derived pyrolysis oil to yield a purified plastic-derived pyrolysis oil comprising 5 wppm or less of silicon and 1 wppb or less of mercury; and steam
15 cracking the plastic-derived pyrolysis oil in the presence of a steam to produce a product.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The following figures are included to illustrate certain aspects of the embodiments, and should not be viewed as exclusive embodiments. The subject matter disclosed is capable of considerable modifications, alterations, combinations, and equivalents in form and function,
20 as will occur to those skilled in the art and having the benefit of this disclosure.

[0011] FIG. 1 is a diagram illustrating a process for reducing/removing silicon from a plastic-derived pyrolysis oil upstream of a steam cracking unit.

[0012] FIG. 2 is a diagram illustrating a process for reducing/removing mercury from a plastic-derived pyrolysis oil upstream of a steam cracking unit.

25 [0013] FIG. 3 is a diagram illustrating a process for reducing/removing silicon and mercury from a plastic-derived pyrolysis oil upstream of a steam cracking unit.

DETAILED DESCRIPTION

[0014] The present disclosure relates to methods and systems for removing silicon and/or mercury contaminants from plastic-derived pyrolysis oil. More specifically, in the methods
30 and systems described herein, the plastic-derived pyrolysis oil is produced from plastic waste material in a plastic pyrolyzer where the plastic material is chemically broken down and then distilled. A plastic-derived pyrolysis oil cut is the primary product of the distillation. The plastic-derived pyrolysis oil is treated to reduce/remove silicon and/or mercury contaminants and then further processed by steam cracking to further reduce the carbon number. The

resultant product is further processed to produce cuts suitable for use in various syntheses including polymers synthesis. While the present disclosure focuses on treating the plastic-derived pyrolysis oil upstream of steam cracking, additionally or alternative to the upstream treating, the product (or a fraction thereof) from the steam cracker may be treated to
5 reduce/remove silicon and/or mercury contaminants.

[0015] As used herein, a reference to a “C_x” fraction, stream, portion, feed, or other quantity is defined as a fraction (or other quantity) where 50 wt% or more of the fraction corresponds to hydrocarbons having “x” number of carbons. When a range is specified, such as “C_x-C_y”, 50 wt% or more of the fraction corresponds to hydrocarbons having a number of
10 carbons from “x” to “y”. A specification of “C_{x+}” (or “C_{x-}”) corresponds to a fraction where 50 wt% or more of the fraction corresponds to hydrocarbons having the specified number of carbons or more (or the specified number of carbons or less).

[0016] As used herein, “plastic-derived pyrolysis oil” refers to pyrolysis oil where at least 50 wt% of the pyrolysis oil is derived from a plastic source. That is, the feedstock (also referred
15 to as plastic feedstock) that is pyrolyzed comprises at least 50 wt% plastic.

[0017] Examples of plastic sources include, but are not limited to, plastic waste (*e.g.*, plastic straws, plastic utensils, plastic bags, food containers, and the like), composite materials (*e.g.*, composite packaging), and the like, and any combination thereof. Said plastic sources may comprise one or more polymers that include, but are not limited to, polyolefins (*e.g.*,
20 homopolymer or copolymers of ethylene, propylene, butene, hexene, butadiene, isoprene, isobutylene, and other olefins), polystyrene, polyvinylchloride, polyamide (*e.g.*, nylon), polyethylene terephthalate, polyurethane, ethylene vinyl acetate, and the like. Other materials may be used in combination with the plastic source to produce the plastic-derived pyrolysis oil, for example, paper, cardboard, textiles, tissues, and the like, and any combination thereof. The
25 plastic portion of the plastic feedstock for pyrolysis may comprise polyolefin at 65 wt% to 100 wt% (or 65 wt% to 80 wt%, or 75 wt% to 90 wt%, or 80 wt% to 100 wt%) with a balance of one or more other polymers.

[0018] Pyrolysis of the plastic feedstock may be performed by known methods and in known systems (*e.g.*, at temperatures of 400°C to 850°C, or 400°C to 600°C, or 500°C to
30 850°C). The pyrolysis product is then distilled (or separated) into one or more cuts including a plastic-derived pyrolysis oil cut.

[0019] The plastic-derived pyrolysis oil may be a C₅₊ stream (or a C₅-C₃₀ stream, or a C₅-C₂₀ stream, or a C₅-C₂₅ stream, or a C₅-C₂₀ stream). The plastic-derived pyrolysis oil

may comprise 50 wt% or more (or 50 wt% to 100 wt%, or 50 wt% to 75 wt%, or 70 wt % to 90 wt%, or 80 wt% to 100 wt%) of C₅₊ hydrocarbons and less than 50 wt% (or 0 wt% to less than 50 wt%, or 25 wt% to 50 wt%, or 10 wt % to 30 wt%, or 0 wt% to 20 wt%, or 0 wt% to 5 wt%, or 0 wt% to 2 wt%) of C₄₋ hydrocarbons.

5 **[0020]** The plastic-derived pyrolysis oil may have a specific gravity of 0.5 to 1.0 (or 0.5 to 0.7, or 0.6 to 0.9, or 0.7 to 1.0).

[0021] The plastic-derived pyrolysis oil may comprise 0 wt% to 60 wt% olefin content, 0 wt% to 25 wt% diolefin content, and balance other species like aromatics and paraffins for example.

10 **[0022]** The plastic-derived pyrolysis oil may have an initial boiling point of 30°C or greater (or 30°C to 200°C, or 30°C to 70°C, or 50°C to 150°C, or 100°C to 200°C). The plastic-derived pyrolysis oil may have a final boiling point of 600°C or less (or 150°C to 600°C, or 250°C to 400°C, or 300°C to 500°C, or 400°C to 600°C).

15 **[0023]** The plastic-derived pyrolysis oil may have properties similar to a naphtha, a distillate, a wax, an atmospheric resid, and the like.

[0024] Depending on the plastic feedstock source, the plastic-derived pyrolysis oil may comprise silicon at 1 wppm to 50 wppm (or 1 wppm to 15 wppm, or 10 wppm to 30 wppm, or 25 wppm to 50 wppm) and/or mercury at 1 wppb to 500 wppb (or 1 wppb to 50 wppb, or 25 wppb to 100 wppb, or 50 wppb to 250 wppb, or 200 wppb to 350 wppb, or 250 wppb to 500 wppb, or 400 wppb to 500 wppb).

[0025] Generally, the methods and systems described herein treat the plastic-derived pyrolysis oil to reduce or remove the silicon and/or mercury contaminants and produce a purified plastic-derived pyrolysis oil that is then treated by steam cracking. FIGS. 1-3 provide nonlimiting example diagrams illustrating said process.

25 **[0026]** FIG. 1 is a diagram illustrating a process **100** for reducing/removing silicon from a plastic-derived pyrolysis oil **102** upstream of a steam cracking unit **116**. The process **100** includes treating the plastic-derived pyrolysis oil **102** in a silicon removal unit **104** to produce a purified plastic-derived pyrolysis oil **106** having a silicon concentration of 5 wppm or less (*e.g.*, 0 wppm to 5 wppm, or 0.001 wppm to 1 wppm, or 0.001 wppm to 0.5 wppm, or 0.001 wppm to 0.1 wppm), where the silicon concentration in the purified plastic derived pyrolysis oil **106** is less than the silicon concentration in the plastic-derived pyrolysis oil **102**. The purified plastic-derived pyrolysis oil **106** is then mixed with a steam cracker feed **110** to produce a mixed feed **114**. In the illustrated example, the purified plastic-derived pyrolysis oil **106** is admixed with the steam cracker feed **110** using a valve **108**. Alternatively, the purified

plastic-derived pyrolysis oil **106** and the steam cracker feed **110** may be mixed in a vessel (not shown) or by any other suitable method to produce the mixed feed **114**. Alternatively, the steam cracker feed **110** and the purified plastic-derived pyrolysis oil **106** can be fed separately (not shown) steam cracking unit **116**. Alternatively (not illustrated), the purified plastic-derived pyrolysis oil **106** can be steam cracked without use of steam cracker feed **110**. That is, the purified plastic-derived pyrolysis oil **106** can be used neat as the feed for the steam cracking unit **116**.

[0027] The mixed feed **114** (or the steam cracker feed **110** and the purified plastic-derived pyrolysis oil **106** separately (not shown), or the purified plastic-derived pyrolysis oil **106** neat (not shown)) and steam **112** are fed into the steam cracking unit **116** for steam cracking to produce a product **118**.

[0028] The mixed feed **114** can comprise the purified plastic-derived pyrolysis oil **106** at 1 wt% to 80 wt% (or 1 wt% to 5 wt%, or 1 wt% to 15 wt%, or 10 wt% to 25 wt%, or 20 wt% to 50 wt%, or 25 wt% to 65 wt%, or 50 wt% to 80 wt%) based on the total weight of the mixed feed **114**.

[0029] The product **118** from the steam cracking unit **116** can then be processed in a recovery facility/unit(s) **120** to produce one or more products **122** suitable for use in various syntheses including polymer synthesis.

[0030] Optionally, the silicon removal unit **104** can include a regenerable adsorbent where a regeneration gas **124** can be passed over the regenerable adsorbent in the silicon removal unit **104** at elevated temperatures to produce a spent regeneration gas **126** comprising silicon.

[0031] Accordingly, a method of the present disclosure can include: removing silicon from a plastic-derived pyrolysis oil to yield a purified plastic-derived pyrolysis oil comprising 5 wppm or less of silicon; and steam cracking the plastic-derived pyrolysis oil in the presence of steam to produce a product.

[0032] Accordingly, a system of the present disclosure can include: a silicon removal unit **104** upstream of and fluidly coupled to a steam cracking unit **116** configured to receive purified plastic-derived pyrolysis oil **106** from the silicon removal unit **104**.

[0033] FIG. 2 is a diagram illustrating a process **200** for reducing/removing mercury from a plastic-derived pyrolysis oil **202** upstream of a steam cracking unit **216**. The process **200** includes treating the plastic-derived pyrolysis oil **202** in a mercury removal unit **204** to produce a purified plastic-derived pyrolysis oil **206** having a mercury concentration of 1 wppb or less (e.g., 0 wppb to 1 wppb, or 0.001 wppb to 1 wppb, or 0.001 wppb to 0.5 wppb, or 0.001 wppb to 0.1 wppb). The purified plastic-derived pyrolysis oil **206** is then mixed with a steam cracker

feed **210** (e.g., steam cracker feeds **110** described above) to produce a mixed feed **214**. In the illustrated example, the purified plastic-derived pyrolysis oil **206** is admixed with the steam cracker feed **210** using a valve **208**. Alternatively, the purified plastic-derived pyrolysis oil **206** and the steam cracker feed **210** may be mixed in a vessel (not shown) or by any other
5 suitable method to produce the mixed feed **214**. Alternatively, the steam cracker feed **210** and the purified plastic-derived pyrolysis oil **206** can be fed separately (not shown) steam cracking unit **216**. Alternatively (not illustrated), the purified plastic-derived pyrolysis oil **106** can be steam cracked without use of steam cracker feed **110**. That is, the purified plastic-derived pyrolysis oil **206** can be used neat as the feed for the steam cracking unit **216**.

10 **[0034]** The mixed feed **214** (or the steam cracker feed **210** and the purified plastic-derived pyrolysis oil **206** separately (not shown), or the purified plastic-derived pyrolysis oil **206** neat (not shown)) and steam **212** are fed into the steam cracking unit **216** for steam cracking to produce a product **218**.

[0035] The mixed feed **214** can comprise the purified plastic-derived pyrolysis oil **206** at
15 1 wt% to 80 wt% (or 1 wt% to 5 wt%, or 1 wt% to 15 wt%, or 10 wt% to 25 wt%, or 20 wt% to 50 wt%, or 25 wt% to 65 wt%, or 50 wt% to 80 wt%) based on the total weight of the mixed feed **214**.

[0036] The product **218** from the steam cracking unit **216** can then be processed in a recovery facility/unit(s) **220** to produce one or more products **222** suitable for use in various
20 syntheses including polymer synthesis.

[0037] Optionally, the mercury removal unit **204** can include a regenerable adsorbent where a regeneration gas **224** can be passed over the regenerable adsorbent in the mercury removal unit **204** at elevated temperatures to produce a spent regeneration gas **226** comprising mercury. Depending on the level of mercury in the spent regeneration gas **226**, the spent
25 regeneration gas **226** may be passed through a mercury trap bed **228** to produce a reduced-mercury gas **230** that can be vented or recycled as regeneration gas **224**.

[0038] Accordingly, a method of the present disclosure can include: removing mercury from a plastic-derived pyrolysis oil to yield a purified plastic-derived pyrolysis oil comprising 1 wppb or less of mercury; and steam cracking the plastic-derived pyrolysis oil in the presence
30 of a steam to produce a product.

[0039] Accordingly, a system of the present disclosure can include: a mercury removal unit **204** upstream of and fluidly coupled to a steam cracking unit **216** configured to receive purified plastic-derived pyrolysis oil **206** from the mercury removal unit **204**.

[0040] FIG. 3 is a diagram illustrating a process **300** for reducing/removing silicon and mercury from a plastic-derived pyrolysis oil **302** upstream of a steam cracking unit **320**. The process **300** includes treating the plastic-derived pyrolysis oil **302** in first in a silicon removal unit **304** to produce a partially purified plastic-derived pyrolysis oil **306** then in a mercury removal unit **308** to produce a purified plastic-derived pyrolysis oil **310** having a silicon concentration of 5 wppm or less (*e.g.*, 0 wppm to 5 wppm, or 0.001 wppm to 1 wppm, or 0.001 wppm to 0.5 wppm, or 0.001 wppm to 0.1 wppm) and a mercury concentration of 1 wppb or less (*e.g.*, 0 wppb to 1 wppb, or 0.001 wppb to 1 wppb, or 0.001 wppb to 0.5 wppb, or 0.001 wppb to 0.1 wppb), where the silicon and mercury concentrations in the purified plastic derived pyrolysis oil **310** is less than the silicon and mercury concentrations, respectively, in the plastic-derived pyrolysis oil **302**. The purified plastic-derived pyrolysis oil **310** is then mixed with a steam cracker feed **314** (*e.g.*, steam cracker feeds **110** described above) to produce a mixed feed **318**. In the illustrated example, the purified plastic-derived pyrolysis oil **310** is admixed with the steam cracker feed **314** using a valve **312**. Alternatively, the purified plastic-derived pyrolysis oil **310** and the steam cracker feed **314** may be mixed in a vessel (not shown) or by any other suitable method to produce the mixed feed **318**. Alternatively, the steam cracker feed **314** and the purified plastic-derived pyrolysis oil **310** can be fed separately (not shown) steam cracking unit **320**. Alternatively (not illustrated), the purified plastic-derived pyrolysis oil **106** can be steam cracked without use of steam cracker feed **110**. That is, the purified plastic-derived pyrolysis oil **310** can be used neat as the feed for the steam cracking unit **320**.

[0041] The mixed feed **318** (or the steam cracker feed **314** and the purified plastic-derived pyrolysis oil **310** separately (not shown), or the purified plastic-derived pyrolysis oil **310** neat (not shown)) and steam **316** are fed into the steam cracking unit **320** for steam cracking to produce a product **322**.

[0042] The mixed feed **318** can comprise the purified plastic-derived pyrolysis oil **310** at 1 wt% to 80 wt% (or 1 wt% to 5 wt%, or 1 wt% to 15 wt%, or 10 wt% to 25 wt%, or 20 wt% to 50 wt%, or 25 wt% to 65 wt%, or 50 wt% to 80 wt%) based on the total weight of the mixed feed **318**.

[0043] The product **322** from the steam cracking unit **320** can then be processed in a recovery facility/unit(s) **324** to produce one or more products **326** suitable for use in various syntheses including polymer synthesis.

[0044] Optionally, the silicon removal unit **304** can include a regenerable adsorbent where a regeneration gas **328** can be passed over the regenerable adsorbent in the silicon removal unit **104** at elevated temperatures to produce a spent regeneration gas **330** comprising silicon.

[0045] Optionally, the mercury removal unit **308** can include a regenerable adsorbent where a regeneration gas **332** can be passed over the regenerable adsorbent in the mercury removal unit **308** at elevated temperatures to produce a spent regeneration gas **334** comprising mercury. Depending on the level of mercury in the spent regeneration gas **334**, the spent
5 regeneration gas **334** may be passed through a mercury trap bed **336** to produce a reduced-mercury gas **338** that can be vented or recycled as regeneration gas **332**.

[0046] Accordingly, a method of the present disclosure can include: removing silicon and mercury from a plastic-derived pyrolysis oil to yield a purified plastic-derived pyrolysis oil comprising 5 wppm or less of silicon and 1 wppb or less of mercury; and steam cracking the
10 plastic-derived pyrolysis oil in the presence of a steam to produce a product.

[0047] Accordingly, a system of the present disclosure can include: a silicon removal unit **304** and a mercury removal unit **308** in series and each upstream of a steam cracking unit **320** configured to receive purified plastic-derived pyrolysis oil **310** from the silicon removal unit **304** or the mercury removal unit **308**.

15 [0048] Again, while the present disclosure focuses on treating the plastic-derived pyrolysis oil upstream of steam cracking, in addition to or alternative of the upstream treating, the product (or a fraction thereof) from the steam cracker may be treated to reduce/remove silicon and/or mercury contaminants.

Silicon Removal

20 [0049] Removal of silicon from the pyrolysis oil can be by any known method.

[0050] For example, removal of the silicon can be achieved by passing the plastic-derived pyrolysis oil over an adsorbent (*e.g.*, a mixture of a lamellar double hydroxide like hydrotalcite and a hydrogenating metal like a group VI-B or group VIII metal, preferably Mo) in the presence of hydrogen at temperatures of 80°C to 360°C and a pressure of 70 psig to 750 psig,
25 which is described in more detail in US Patent No. 8,106,250, which is incorporated herein by reference.

[0051] Another method of removing silicon from the plastic-derived pyrolysis oil includes passing the plastic-derived pyrolysis oil over an adsorbent (*e.g.*, a mixture of copper oxide and a porous, inorganic refractory oxide containing at least 10 wt% alumina) in the presence of
30 hydrogen at temperatures of 80°C to 500°C and a pressure of atmospheric pressure to 1000 psig, which is described in more detail in US Patent No. 4,645,587, which is incorporated herein by reference.

Mercury Removal

[0052] Removal of mercury from the pyrolysis oil can be by any known method.

[0053] Removal of mercury can be achieved by passing the plastic-derived pyrolysis oil over an adsorbent (*e.g.*, metallic copper, gold, silver, nickel, thallium, platinum, palladium, gallium, and/or indium dispersed on an oxide support) in the presence of hydrogen at temperatures of 25°C to 100°C and a pressure of 0 psig to 300 psig, which is described in more detail in US Patent No. 5,463,167, which is incorporated herein by reference.

[0054] Another method of removing mercury from the plastic-derived pyrolysis oil includes contacting the plastic-derived pyrolysis oil with a sulfur compound (*e.g.*, $MM'S_x$ where M is selected from a group consisting of alkali metal and ammonium radical, M' is selected from a group consisting of alkali metal, ammonium radical, and hydrogen, and x is a number of at least 1) to produce a mercury sulfide. Then, the mercury sulfide and other mercury compounds in the plastic-derived pyrolysis oil can be removed by passing the plastic-derived pyrolysis oil over an adsorbent (*e.g.*, adsorbents described above) in the presence of hydrogen at temperatures of 25°C to 100°C and a pressure of 0 psig to 300 psig.

[0055] Yet another method of removing mercury from the plastic-derived pyrolysis oil includes passing the plastic-derived pyrolysis oil over a sulfur-impregnated metal oxide filter or bed and/or a carbon-impregnated metal oxide filter or bed. Such filters/beds trap the mercury by reacting with the mercury compound and maintaining the mercury in the filter/bed. Such mechanisms are not regenerable and therefore, can be used in the mercury trap in FIGS. 2 and 3 or in the mercury removal unit of FIGS. 2 and 3 where the optional regeneration is not included.

Steam Cracking

[0056] Steam cracking is a type of a pyrolysis process. In various aspects, the feed for steam cracking can correspond to any type of liquid feed (*i.e.*, feed that is liquid at 20°C and 100 kPa-a, as defined herein). Examples of suitable steam cracking feeds can include hydrocarbon gases (*e.g.*, ethane, propane, and the like), whole and partial crudes, naphtha boiling feeds, distillate boiling range feeds, resid boiling range feeds (atmospheric or vacuum), or combinations thereof. Although certain aspects of the present disclosure are described with reference to particular feeds the present disclosure is not limited thereto, and this description is not meant to exclude other feeds within the broader scope of the present disclosure.

Example Embodiments

[0057] A first nonlimiting example embodiment of the present disclosure is a method comprising: removing silicon from a plastic-derived pyrolysis oil to yield a purified plastic-derived pyrolysis oil comprising 5 wppm or less of silicon; and steam cracking the plastic-derived pyrolysis oil in the presence of steam to produce a product. Said embodiment may also

include one or more of the following: Element 1: wherein steam cracking the plastic-derived pyrolysis oil is further in the presence of a steam cracker feed; Element 2: Element 1 and admixing the purified plastic-derived pyrolysis oil with the steam cracker feed to yield a mixed feed; and steam cracking the mixed feed; Element 3: Element 2 and wherein the mixed feed
5 comprises the plastic-derived pyrolysis oil at 1 wt% to 80 wt% based on the weight of the mixed feed; Element 4: wherein removing the silicon from the plastic-derived pyrolysis oil comprises: contacting the plastic-derived pyrolysis oil with an adsorbent; and Element 5: Element 4 and wherein contacting the plastic-derived pyrolysis oil with the adsorbent is in the presence of hydrogen. Examples of combinations include, but are not limited to, Element 1
10 optionally in combination with Element 2 and Element 3 in combination with Element 4 and optionally Element 5; and Elements 1 and 2 in combination with Element 4 and optionally Element 5.

[0058] A second nonlimiting example embodiment of the present disclosure is a method comprising: removing mercury from a plastic-derived pyrolysis oil to yield a purified plastic-
15 derived pyrolysis oil comprising 1 wppb or less of mercury; and steam cracking the plastic-derived pyrolysis oil in the presence of a steam to produce a product. Said embodiment may also include one or more of the following: Element 1; Element 2; Element 3; Element 6: wherein removing the mercury from the plastic-derived pyrolysis oil comprises: contacting the plastic-derived pyrolysis oil with an adsorbent in the presence of hydrogen; Element 7:
20 Element 6 and the method further comprising; regenerating the adsorbent; and Element 8: wherein removing the mercury from the plastic-derived pyrolysis oil comprises: passing the plastic-derived pyrolysis oil through a mercury trap. Examples of combinations include, but are not limited to, Element 1 optionally in combination with Element 2 and Element 3 in combination with Element 6 and optionally Element 7; Elements 1 and 2 in combination with
25 Element 6 and optionally Element 7; Element 1 optionally in combination with Element 2 and Element 3 in combination with Element 8; Elements 1 and 2 in combination with 8; and Elements 6 and 8 an optionally Element 7 in combination and optionally in further combination with one or more of Elements 1-3.

[0059] A third nonlimiting example embodiment of the present disclosure is a method
30 comprising: removing silicon and mercury from a plastic-derived pyrolysis oil to yield a purified plastic-derived pyrolysis oil comprising 5 wppm or less of silicon and 1 wppb or less of mercury; and steam cracking the plastic-derived pyrolysis oil in the presence of a steam to produce a product. Said embodiment may also include one or more of the following: Element 1; Element 2; Element 3; Element 4; Element 5; Element 6; Element 7; and Element 8.

Examples of combinations include, but are not limited to, two or more of Elements 1-3 in combination; two or more of Elements 4-8 in combination; and one or more of Elements 1-3 in combination with one or more of Elements 4-8.

[0060] Unless otherwise indicated, all numbers expressing quantities of ingredients, properties such as molecular weight, reaction conditions, and so forth used in the present specification and associated claims are to be understood as being modified in all instances by the term “about.” Accordingly, unless indicated to the contrary, the numerical parameters set forth in the following specification and attached claims are approximations that may vary depending upon the desired properties sought to be obtained by the embodiments of the present invention. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claim, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques.

[0061] One or more illustrative embodiments incorporating the invention embodiments disclosed herein are presented herein. Not all features of a physical implementation are described or shown in this application for the sake of clarity. It is understood that in the development of a physical embodiment incorporating the embodiments of the present invention, numerous implementation-specific decisions must be made to achieve the developer’s goals, such as compliance with system-related, business-related, government-related and other constraints, which vary by implementation and from time to time. While a developer’s efforts might be time-consuming, such efforts would be, nevertheless, a routine undertaking for those of ordinary skill in the art and having benefit of this disclosure.

[0062] While compositions and methods are described herein in terms of “comprising” various components or steps, the compositions and methods can also “consist essentially of” or “consist of” the various components and steps.

[0063] Therefore, the present invention is well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only, as the present invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular illustrative embodiments disclosed above may be altered, combined, or modified and all such variations are considered within the scope and spirit of the present invention. The invention illustratively disclosed herein suitably may be practiced in the absence of any element that is not specifically disclosed herein and/or any optional element disclosed herein. While

compositions and methods are described in terms of “comprising,” “containing,” or “including” various components or steps, the compositions and methods can also “consist essentially of” or “consist of” the various components and steps. All numbers and ranges disclosed above may vary by some amount. Whenever a numerical range with a lower limit and an upper limit

5 is disclosed, any number and any included range falling within the range is specifically disclosed. In particular, every range of values (of the form, “from about a to about b,” or, equivalently, “from approximately a to b,” or, equivalently, “from approximately a-b”) disclosed herein is to be understood to set forth every number and range encompassed within the broader range of values. Also, the terms in the claims have their plain, ordinary meaning

10 unless otherwise explicitly and clearly defined by the patentee. Moreover, the indefinite articles “a” or “an,” as used in the claims, are defined herein to mean one or more than one of the element that it introduces.