

SUMMARY

[00018] The present disclosure provides a method for treating a carbonaceous feedstock. In the method, at least one oxidizing agent selected from an oxygen-containing gas, hydrogen peroxide, ozone and oxidizing acids is adsorbed from a liquid phase of an aqueous mixture comprising water, the at least one oxidizing agent and the carbonaceous feedstock, onto the carbonaceous feedstock under conditions at which substantially no oxidation of the carbonaceous feedstock will occur in order to produce an aqueous mixture with the liquid phase having a reduced content of the oxidizing agent and a carbonaceous feedstock having oxidizing agent adsorbed on a surface thereof. The carbonaceous feedstock with adsorbed oxidizing agent is then heated in an aqueous mixture having a liquid phase that contains a low content of oxidizing agent to a temperature and for a sufficient time to oxidize at least a portion of the carbonaceous feedstock.

[00018a] In one aspect of the present disclosure, there is provided a method for treating a carbonaceous feedstock, comprising the steps of

adsorbing at least one oxidizing agent selected from an oxygen-containing gas, hydrogen peroxide, ozone and oxidizing acids from a liquid phase of an aqueous mixture comprising water, at least one oxidizing agent and the carbonaceous feedstock, onto the carbonaceous feedstock under conditions at which substantially no oxidative depolymerization of carbonaceous materials of the carbonaceous feedstock will occur in order to produce an aqueous mixture with the liquid phase having a reduced content of the oxidizing agent and the carbonaceous feedstock having oxidizing agent adsorbed on a surface thereof; and

heating the aqueous mixture produced in the adsorbing step to a temperature and for a sufficient time to oxidatively depolymerize and solubilize at least a portion of the carbonaceous feedstock.

[00019] In another embodiment, the method of the present disclosure includes multiple heating steps, each of which preferably is conducted using at least one different condition selected from temperature, pressure, duration, or using a different oxidizing agent.

[00020] In yet another embodiment, the method of the present disclosure at least one catalyst is present in the aqueous mixture during at least one of the heating steps.

[00021] In another embodiment, the method of the present disclosure is conducted with at least one solubilizing agent in the aqueous mixture during at least one of the heating steps.

[00022] In another embodiment, the method of the present disclosure the aqueous mixture is provided by mixing an oxidizing agent and a suspension of carbonaceous material in water.

[00023] In yet another embodiment, the method of the present disclosure the aqueous mixture is provided by mixing a suspension of carbonaceous material with an aqueous solution of the oxidizing agent.

[00024] In yet another embodiment, the method of the present disclosure further comprises the steps of: chemical and/or physical separation of the product of the one or more heating steps; and/or microbial digestion of the product of the one or more heating steps.

BRIEF DESCRIPTION OF THE DRAWINGS

[00025] Figure 1 is a flow chart that shows a method according to one embodiment of the present invention.

[00026] Figure 2 shows a diagram of conversion of coal to valuable organic compounds (per gram of coal) as produced in Example 1.

WHAT IS CLAIMED IS:

1. A method for treating a carbonaceous feedstock, comprising the steps of
adsorbing at least one oxidizing agent selected from an oxygen-containing gas, hydrogen peroxide, ozone and oxidizing acids from a liquid phase of an aqueous mixture comprising water, at least one oxidizing agent and the carbonaceous feedstock, onto the carbonaceous feedstock under conditions at which substantially no oxidative depolymerization of carbonaceous materials of the carbonaceous feedstock will occur in order to produce an aqueous mixture with the liquid phase having a reduced content of the oxidizing agent and the carbonaceous feedstock having oxidizing agent adsorbed on a surface thereof; and
heating the aqueous mixture produced in the adsorbing step to a temperature and for a sufficient time to oxidatively depolymerize and solubilize at least a portion of the carbonaceous feedstock.
2. The method of claim 1, wherein the oxidizing agent is an oxygen-containing gas selected from air, oxygen enriched air, and pure oxygen.
3. The method of any one of claims 1-2, wherein the aqueous mixture contains the carbonaceous feedstock in a range of from about 10 wt.% to about 70 wt.% of a total weight of the aqueous mixture, or from about 15 wt.% to about 60 wt.% of a total weight of the aqueous mixture, or from about 20 wt.% to about 50 wt.% of the total weight of the aqueous mixture, or from about 25 wt.% to about 45 wt.% of the total weight of the aqueous mixture.
4. The method of any one of claims 1-3, wherein the adsorbing step is carried out a temperature below about 220 °C, or below about 210 °C, or below about 200 °C, or below about 190 °C, or below about 180 °C, or below about 170 °C, or below about 160 °C, or below about 150 °C, or below about 140 °C, or below about 130 °C, or below about 120 °C.
5. The method of any one of claims 1-4, wherein the adsorbing step is carried out for a period of less than about 1 hour, or less than about 50 minutes, or less than about 40 minutes, or less than about 30 minutes, or less than about 20 minutes, or less than about 10 minutes, or less than about 8 minutes, or less than about 5 minutes.
6. The method of any one of claims 1-5, wherein the products of the heating step

have an O/C molar ratio that is from 30% to 200%, or from 40% to 180%, or from 50% to 160%, or from 60% to 140%, or from 70% to 120%, or from 80% to 100%, higher than the O/C molar ratio of the carbonaceous feedstock.

7. The method of any one of claims 1-6, wherein the heating step is carried out at a temperature higher than a temperature of the adsorbing step and less than about 250 °C, or less than about 240 °C, or less than about 230 °C, or less than about 220 °C, or less than about 210 °C, or less than about 200 °C, or less than about 190 °C, or less than about 180 °C, or less than about 170 °C, or less than about 160 °C.

8. The method of any one of claims 1-7, wherein the adsorbing step comprises reacting the oxidizing agent with the carbonaceous materials to form oxides selected from peroxide, epoxide, and hydroperoxide.

9. The method of any one of claims 1-8, wherein the heating step is carried out for a period of less than about 4 hours, or less than about 3.5 hours, or less than about 3 hours, or less than about 2.5 hours, or less than about 2 hours, or less than about 1.75 hours, or less than about 1.5 hours, or less than about 1.25 hours, or less than about 1 hour, or less than about 0.75 hour, or less than about 0.5 hour, or less than about 0.25 hour.

10. The method of any one of claims 1-9, wherein the heating step is configured as multiple heating steps.

11. The method of claim 10, wherein each of the multiple heating steps is carried out under at least one different condition selected from temperature, pressure, duration and/or using an additional oxidizing agent.

12. The method of any one of claims 1-11, wherein the heating step is carried out in the presence of at least one catalyst for oxidation selected from water insoluble metals, transition metals, precious metals, alkali metals, alkaline earth metals and mixtures thereof.

13. The method of any one of claims 1-12, the aqueous mixture comprises at least one solubilizing agent selected from mineral acids and mineral bases during the heating step.

14. The method of any one of claims 1-13, further comprising a preprocessing step selected from grinding, milling or crushing of the carbonaceous feedstock.
15. The method of any one of claims 1-14, further comprising a step of producing the aqueous mixture by mixing the oxidizing agent and carbonaceous feedstock in water.
16. The method of any one of claims 1-14, further comprising a step of producing the aqueous mixture by mixing the carbonaceous feedstock and an aqueous solution of the oxidizing agent.
17. The method of any one of claims 1-16, further comprising the step of chemically and/or physically separating at least one component from a product of the heating step.
18. The method of claim 17, wherein a component obtained from the chemical and/or physical separating step is recycled to the adsorbing step.
19. The method of claim 17, wherein a component obtained from the chemical and/or physical separating step is recycled to the heating step.
20. The method of any one of claims 1-19, further comprising a step of microbial digestion of one or more water soluble carbonaceous products of the heating step.
21. The method of claim 20, wherein a component of a product of the microbial digestion step is recycled to the heating step.
22. The method of any one of claims 20-21, wherein the microbial digesting step is a process selected from an aerobic process, an anaerobic process and a combination of an aerobic and an anaerobic process.
23. The method of any one of claims 1-22, wherein the carbonaceous feedstock is selected from the group consisting of coal, lignite, tar sands, tars, crude oils, peat, pitch, resins, lignin, latex rubber, waxes, agricultural wastes, bark, wood, forestry wastes, and algae cake, municipal solid waste, waste plastics, other lignocellulosic biomass.

24. The method of any one of claims 1-23, further comprising a step of enzymatic digestion of one or more water soluble carbonaceous products of the heating step.
25. The method of any one of claims 1-16, wherein the carbonaceous material is a lignocellulosic biomass.
26. The method of claim 25, further comprising a post-treatment step for reducing the size of solids in the product of heating step or softening the solids in the product of heating step.
27. The method of any one of claims 25-26, wherein the solids are separated from a liquid portion of the product of heating step before the post-treatment step.
28. The method of any one of claims 25-27, wherein the post-treatment step is carried out using a technique selected from steam explosion, ball milling, hammer milling, grinding, refining, compression milling, impact milling, mechanical ripping or tearing, pin grinding or air attrition milling and mechanical pulping.
29. The method of any one of claims 25-28, further comprising a step of swelling the lignocellulosic biomass with water and/or steam prior to the adsorbing step.
30. The method of claim 29, wherein the swelling step is carried out at a temperature in a range of from about 25 °C to about 100 °C, or from about 30 °C to about 90 °C, or from about 35 °C to about 80 °C, or from about 35 °C to about 70 °C, or from about 40 °C to about 70 °C, or from about 45 °C to about 70 °C, or from about 45 °C to about 65 °C, or from about 50 °C to about 65 °C.
31. The method of any one of claims 29-30, wherein the swelling step is carried out under a pressure less than about 30 psi, or less than about 28 psi, or less than about 26 psi, or less than about 24 psi, or less than about 22 psi, or less than about 20 psi, or less than about 18 psi, or less than about 16 psi.
32. The method of any one of claims 25-31, further comprising a step of separating a component comprising one or more organic acids from the product of step.

33. The method of claim 32, wherein the component comprising one or more organic acids is separated from the product of step by a technique selected from liquid-liquid extraction, gas stripping, steam stripping and distillation.
34. The method of any one of claims 32-33, wherein the one or more organic acids are recycled to a step selected from the swelling step, the adsorbing step and the heating step.
35. The method of any one of claims 28-34, further comprising the step of washing solids separated from a product of the post-treatment step with water.
36. The method of claim 35, wherein the washed solids are subsequently dried.
37. The method of any one of claims 27-36, wherein the liquid portion is subjected to microbial fermentation.
38. The method of any one of claims 27-36 further comprising a step of converting a cellulose-containing solid product of the method to a paper product.