Claims

1. A method for removing a trace amount of mercury in a natural gas feed, comprising:

recovering a mixture of produced water and mercury-containing natural gas from an underground reservoir;

separating the mercury-containing natural gas from the produced water;

scrubbing the mercury-containing natural gas with an aqueous solution in an absorber, wherein the aqueous solution comprises the produced water and a water-soluble sulfur compound to react a least a portion of the mercury in the natural gas with the water-soluble sulfur compound to produce a treated natural gas with a reduced concentration of mercury and a mercury-containing sulfur-depleted solution, removing at least a portion of the mercury-containing sulfur-depleted solution as a purge stream;

recirculating at least a portion of the mercury-containing sulfur-depleted solution as a recirculating stream; and

providing a fresh source of water-soluble sulfur compound as a feed to the absorber for reaction with the mercury in the natural gas.

2. The method of claim 1, further comprising injecting at least a portion of the purge stream into an underground reservoir.

3. The method of claim 1, wherein less than 1% of the mercury is scrubbed from the natural gas as a solid mercury complex.

4. The method of claim 1, wherein providing a fresh source of water-soluble sulfur compound comprises reacting elemental sulfur with a sulfidic solution.

5. The method of claim 4, wherein the sulfidic solution comprises Na2S.

6. The method of claim 4, wherein the produced water separated from the mercury containing natural gas is added to the reaction of elemental sulfur with a sulfidic solution to provide a fresh source of water-soluble sulfur compound.

7. The method of claim 1, wherein the produced water separated from the mercury containing natural gas is added to the fresh source of water-soluble sulfur compound as a feed to the absorber.

8. The method of claim 1, further comprising filtering the mercury containing sulfur-depleted solution prior to recirculating at least a portion of the mercury containing sulfur-depleted solution.

9. The method of claim 8, further comprising adding the filtered mercury containing sulfur-depleted solution to a fresh source of water-soluble sulfur compound.

10. The method of claim 8, further comprising adding the filtered mercury containing sulfur-depleted solution to a reaction of elemental sulfur with a sulfidic solution to provide a fresh source of water-soluble sulfur compound as a feed to the absorber.

11. The method of claim 1, wherein the water-soluble sulfur compound is selected from sodium hydrosulfide, potassium hydrosulfide, ammonium hydrosulfide, sodium sulfide, potassium sulfide, calcium sulfide, magnesium sulfide, ammonium sulfide, and mixtures thereof.

12. The method of claim 1, wherein the aqueous solution containing a water-soluble sulfur compound comprises any of sulfidic water, sulfidic waste water, kraft caustic liquor, kraft carbonate liquor, and combinations thereof.

13. The method of claim 1, wherein at least 50% of mercury is removed from the natural gas.

14. The method of claim 13, wherein at least 90% of mercury is removed from the natural gas.

15. The method of claim 1, wherein the treated natural gas contains less than 10 µg/Nm3 mercury.

16. The method of claim 15, wherein the treated natural gas contains less than 1 µg/Nm3 mercury.

17. The method of claim 16, wherein the treated natural gas contains less than 0.1 µg/Nm3 mercury.

18. The method of claim 1, wherein the aqueous solution comprising a water-soluble sulfur compound has a pH of at least 8.

19. The method of claim 1, wherein the mercury-containing natural gas is scrubbed with an aqueous solution comprising a water-soluble sulfur compound in a molar ratio of 5:1 to 10,000:1 of sulfur to mercury in the natural gas.

20. The method of claim 1, wherein the mercury-containing natural gas is scrubbed with an aqueous solution comprising a water-soluble sulfur compound having a concentration of sulfur in the aqueous solution from 50 to 20,000 ppmw.

21. The method of claim 1, wherein the method is carried out on a floating production, storage and offloading (FPSO) unit.

22. A method for removing a trace amount of mercury in a natural gas feed, comprising:

recovering a mercury-containing natural gas from an underground reservoir;

scrubbing the mercury-containing natural gas with an aqueous solution in an absorber, wherein the aqueous solution comprises non-potable water selected from connate water, aquifer water, seawater, desalinated water, oil field produced water, industrial by-product water, and combinations thereof, and a water-soluble sulfur compound to react a least a portion of the mercury in the natural gas with the water-soluble sulfur compound to produce a treated natural gas with a reduced concentration of mercury and a mercury-containing sulfur-depleted solution, removing at least a portion of the mercury containing sulfur-depleted solution as a purge stream;

recirculating at least a portion of the mercury containing sulfur-depleted solution as a recirculating stream; and

providing a fresh source of water-soluble sulfur compound as a feed to the absorber for reaction with the mercury in the natural gas.

23. The method of claim 22, wherein providing a fresh source of water-soluble sulfur compound comprises reacting elemental sulfur with a sulfidic solution.

24. The method of claim 22, wherein providing a fresh source of water-soluble sulfur compound comprises adding elemental sulfur and a sulfidic solution to the recirculating stream.

CLAIMS

1. A method for removing a trace amount of mercury in a natural gas feed, comprising:

recovering a mixture of produced water and mercury-containing natural gas from an underground reservoir;

separating the mercury-containing natural gas from the produced water;

scrubbing the mercury-containing natural gas with an aqueous solution in an absorber, wherein the aqueous solution comprises a water-soluble sulfur compound to react a least a portion of the mercury in the natural gas with the water-soluble sulfur compound to produce a treated natural gas with a reduced concentration of mercury and a mercury-containing sulfur-depleted solution,

removing at least a portion of the mercury-containing sulfur-depleted solution as a purge stream;

recirculating at least a portion of the mercury-containing sulfur-depleted solution as a recirculating stream; and

providing a fresh source of water-soluble sulfur compound as a feed to the absorber for reaction with the mercury in the natural gas.

2. The method of claim 1, further comprising injecting at least a portion of the purge stream into an underground reservoir.

3. The method of claim 1, wherein less than 1% of the mercury is scrubbed from the natural gas as a solid mercury complex.

4. The method of claim 1, wherein providing a fresh source of water-soluble sulfur compound comprises reacting elemental sulfur with a sulfidic solution.

5. The method of claim 4, wherein the sulfidic solution comprises Na_2S.

6. The method of claim 4, wherein the produced water separated from the mercury containing natural gas is added to the reaction of elemental sulfur with a sulfidic solution to provide a fresh source of water-soluble sulfur compound.

7. The method of claim 1, wherein the produced water separated from the mercury containing natural gas is added to the fresh source of water-soluble sulfur compound as a feed to the absorber.

8. The method of claim 1, further comprising filtering the mercury containing sulfur-depleted solution prior to recirculating at least a portion of the mercury containing sulfur-depleted solution.

9. The method of claim 8, further comprising adding the filtered mercury containing sulfur-depleted solution to a fresh source of water-soluble sulfur compound.

10. The method of claim 8, further comprising adding the filtered mercury containing sulfur-depleted solution to a reaction of elemental sulfur with a sulfidic solution to provide a fresh source of water-soluble sulfur compound as a feed to the absorber.

11. The method of claim 1, wherein the water-soluble sulfur compound is selected from sodium hydrosulfide, potassium hydrosulfide, ammonium hydrosulfide, sodium sulfide, potassium sulfide, calcium sulfide, magnesium sulfide, ammonium sulfide, and mixtures thereof.

12. The method of claim 1, wherein the aqueous solution containing a water-soluble sulfur compound comprises any of sulfidic water, sulfidic waste water, kraft caustic liquor, kraft carbonate liquor, and combinations thereof.

13. The method of claim 1, wherein at least 50% of mercury is removed from the natural gas.

14. The method of claim 13, wherein at least 90% of mercury is removed from the natural gas.

15. The method of claim 1, wherein the treated natural gas contains less than 10 $\mu g/Nm^3$ mercury.

16. The method of claim 15, wherein the treated natural gas contains less than 1 $\mu g/Nm^3$ mercury.

17. The method of claim 16, wherein the treated natural gas contains less than 0.1 $\mu g/Nm^3$ mercury.

18. The method of claim 1, wherein the aqueous solution comprising a water-soluble sulfur compound has a pH of at least 8.

19. The method of claim 1, wherein the mercury-containing natural gas is scrubbed with an aqueous solution comprising a water-soluble sulfur compound in a molar ratio of 5:1 to 10,000:1 of sulfur to mercury in the natural gas.

20. The method of claim 1, wherein the mercury-containing natural gas is scrubbed with an aqueous solution comprising a water-soluble sulfur compound having a concentration of sulfur in the aqueous solution from 50 to 20,000 ppmw.

21. The method of claim 1, wherein the method is carried out on a floating production, storage and offloading (FPSO) unit.

22. A method for removing a trace amount of mercury in a natural gas feed, comprising:

recovering a mercury-containing natural gas from an underground reservoir;

scrubbing the mercury-containing natural gas with an aqueous solution in an absorber, wherein the aqueous solution comprises a water-soluble sulfur compound to react a least a portion of the mercury in the natural gas with the water-soluble sulfur compound to produce a treated natural gas with a reduced concentration of mercury and a mercury-containing sulfur-depleted solution,

removing at least a portion of the mercury containing sulfur-depleted solution as a purge stream;

recirculating at least a portion of the mercury containing sulfur-depleted solution as a recirculating stream; and

providing a fresh source of water-soluble sulfur compound as a feed to the absorber for reaction with the mercury in the natural gas.

23. The method of claim 22, wherein the aqueous solution is non-potable water selected from connate water, aquifer water, seawater, desalinated water, oil field produced water, industrial by-product water, and combinations thereof.

24. The method of claim 22, wherein providing a fresh source of water-soluble sulfur compound comprises reacting elemental sulfur with a sulfidic solution.

25. The method of claim 22, wherein providing a fresh source of water-soluble sulfur compound comprises adding elemental sulfur and a sulfidic solution to the recirculating stream.