[006] There are also a number of commercially available processes and products for the removal of (volatile) elemental mercury Hg^0 from hydrocarbon streams including but not limited to ICI Synetix' Merespec™ fixed bed absorbents, UOP's HgSIV™ regenerative mercury removal adsorbents, and Johnson Matthey's Puraspec™ and Puracare™ granulated absorbents for the removal of mercury from naphtha and / or gaseous hydrocarbon streams. Adsorption technology does not work well for crude oils and condensates with low levels of mercury, and with primarily non-volatile mercury.

[007] Production of oil and gas is usually accompanied by the production of water. This produced water in some cases is reinjected into the subsurface for disposal, to maintain pressure in the reservoir, or to achieve other beneficial effects. The produced water may consist of formation water (water present naturally in the reservoir), or water previously injected into the formation. As exploited reservoirs mature, the quantity of water produced increases. Produced water is the largest single fluid stream in exploration and production operations.

[008] There is a need for methods for the removal of non-volatile mercury from liquid hydrocarbon streams, and particularly methods wherein produced water can be used / recycled.

SUMMARY OF THE ~~INVENTION~~DISCLOSURE

[009] In one aspect, the ~~invention~~ disclosure relates to an improved method to treat a crude oil to reduce its mercury concentration. The method comprises: extracting crude oil from the ground via a well with associated natural gas and produced water; separating dissolved natural gas and at least a portion of the produced water from the crude oil; mixing into the crude oil at least a portion of the separated produced water and a water-soluble reagent containing a single sulfur atom selected from the group of water-soluble monatomic sulfur compound selected from the group of sodium hydrosulfide, potassium hydrosulfide, ammonium hydrosulfide, sodium sulfide, potassium sulfide, calcium sulfide, magnesium sulfide, and ammonium sulfide and combinations thereof forming a mixture; extracting at least a portion of the mercury into the water as a soluble compound forming a mercury rich wastewater, separating the wastewater from the crude oil for a treated crude oil having a reduced concentration of mercury, and disposal of the mercury-rich wastewater via reinjection to an underground reservoir. In one embodiment, the water stream consists essentially of produced water. In another embodiment, the wastewater is injected into a gas

or oil reservoir. In yet another embodiment, the wastewater is optionally treated before injection into a gas or oil reservoir.

[010] In another embodiment, after separation of the treated crude oil having a reduced concentration of mercury from the mercury-rich wastewater, at least a portion of the mercury-rich wastewater is recycled and combined with the separated produced water and a water-soluble reagent to be contacted with the mercury-containing crude oil. In this way, the mercury-rich wastewater, which still contains unreacted water-soluble sulfur-containing reagent is recycled to reduce the total amount of sulfur-containing reagent required to accomplish removal of mercury from the crude oil. At least a portion of the mercury-rich wastewater is disposed of via reinjection to an underground reservoir.

[010a] In another aspect, there is provided a method for reducing a trace amount of mercury in a crude oil feed, comprising:

recovering a mixture of produced water and crude oil containing mercury from an underground reservoir, wherein at least 50% of the mercury is non-volatile mercury;

mixing into the mixture of produced water and crude oil an effective amount of a water stream comprising a base and at least one of sodium hydrosulfide, sodium sulfide, and combinations thereof;

extracting at least a portion of the non-volatile mercury into produced water as soluble mercury sulfur complexes forming a mercury rich wastewater;

separating the mercury rich wastewater from the crude oil for a treated crude oil having a reduced concentration of non-volatile mercury; and

injecting at least a portion of the mercury rich wastewater into an underground reservoir.

[010b] In another aspect, there is provided a method for removing a trace amount of mercury from a crude oil feed comprising;

extracting a produced fluid containing natural gas, produced water, and crude oil from an underground reservoir via a production well;

separating at least a portion of dissolved natural gas and produced water from the crude oil in the produced fluid to produce a crude oil containing a trace amount of mercury in which at least 50% of the mercury is non-volatile mercury;

combining at least a portion of the separated produced water with a water-soluble monatomic sulfur compound to produce a sulfur-containing produced water solution;

contacting the crude oil containing a trace amount of mercury with at least a portion of the sulfur-containing produced water solution for the mercury to react with the sulfur compound forming a soluble mercury sulfur complex in produced water; and

separating the produced water from the crude oil to generate a treated crude oil having a reduced concentration of mercury and a mercury-containing wastewater stream.

[010c] In another aspect, there is provided a method for removing a trace amount of mercury from a crude oil feed comprising;

extracting a produced fluid from an underground reservoir via a well;

separating at least a portion of dissolved natural gas and produced water from the crude oil in the produced fluid to produce a crude oil containing a trace amount of mercury in which at least 50% of the mercury is non-volatile mercury;

combining at least a portion of the separated produced water with a water-soluble monatomic sulfur compound to produce a sulfur-containing produced water solution;

contacting the separated crude oil with at least a portion of the sulfur-containing produced water solution for the monatomic sulfur compound to react with the mercury in the crude oil forming a treated crude oil having a reduced mercury concentration and a mercury-containing wastewater stream containing soluble mercury sulfur compounds;

separating treated crude oil having a reduced mercury concentration from the mercury-containing wastewater stream; and

recycling at least a portion of the mercury-containing wastewater stream for use in producing a sulfur-containing produced water solution.

BRIEF DESCRIPTION OF THE DRAWINGS

[011] Figure 1 is a block diagram of an embodiment of a mercury removal unit (MRU) and process to remove mercury from crude oil, wherein the wastewater containing soluble mercury complexes is recycled for use as treatment solution or injected into a reservoir.

[012] Figure 2 is a block diagram of another embodiment of the MRU.

[013] Figure 3 is a block diagram of yet another embodiment of a process for mercury removal, wherein the removal is in-situ in a pipeline from a production well to a processing facility.

[014] Figure 4 is a block diagram of yet another embodiment of a process for mercury removal, including equipment for the treatment / removal of mercury from a stripping gas.

DETAILED DESCRIPTION

[015] The following terms will be used throughout the specification and will have the following meanings unless otherwise indicated.

[016] "Hydrocarbons" refers to hydrocarbon streams such as crude oils and / or natural gases.

[017] "Produced fluids" refers hydrocarbon gases and / or crude oil. Produced fluids may be used interchangeably with hydrocarbons.

[018] "Crude oil" refers to a hydrocarbon material, including to both crude oil and condensate, which is typically in liquid form. Under some formation conditions of temperature and/or pressure, the crude may be in a solid phase. Under some conditions, the