CLAIMS

1. A method for reducing a trace amount of heavy metals in a crude oil, comprising:

mixing into the crude oil an effective amount of at least an oxidizing agent selected from the group of hydroperoxides, organic peroxides, inorganic peracids and salts thereof, organic peracids and salts thereof, molecular halogens, ozone and combinations thereof to extract at least a portion of the heavy metals in a water oil emulsion;

separating the extracted heavy metals from the crude oil to obtain a treated crude oil having a reduced concentration of heavy metals.

2. A method for reducing a trace amount of heavy metals in a crude oil, comprising:

mixing into the crude oil an effective amount of at least an oxidizing agent selected from the group of oxyhalites, hydroperoxides, organic peroxides, inorganic peracids and salts thereof, organic peracids and salts thereof, molecular halogens, ozone and combinations thereof to extract at least a portion of the heavy metals into a water oil emulsion;

adding an effective amount of a complexing agent to convert at least a portion of the extracted heavy metals in the water oil emulsion to soluble heavy metal compounds in a water phase; and

separating the water phase containing the soluble heavy metal compounds from the crude oil to obtain a treated crude oil having a reduced concentration of heavy metals.

3. In a method for treating a crude oil to reduce its mercury level, comprising mixing into the crude oil a water stream consisting essentially of an oxidizing agent to convert at least a portion of the mercury to mercury cations, and extracting at least a portion of the mercury cations into the water stream forming a mercury-rich wastewater, and separating the wastewater from the crude oil, leaving a treated crude oil having a reduced concentration of mercury, the improvement comprising:

adding an effective amount of a complexing agent to convert at least a portion of the mercury cations to soluble mercury compounds in a water phase prior to separating the water phase containing soluble mercury compounds from the crude oil to obtain a treated crude oil having a reduced mercury level.

4. A method for reducing a trace amount of arsenic in a crude oil, comprising:

mixing into the crude oil an effective amount of at least an oxidizing agent selected from the group of oxyhalites, hydroperoxides, organic peroxides, inorganic peracids and salts thereof, organic peracids and salts thereof, molecular halogens, ozone and combinations thereof to extract at least a portion of arsenic into a water-oil emulsion as arsenic cations, forming a mixture;

adding an effective amount of a complexing agent to the water-oil emulsion mixture to convert the extracted arsenic cations to water-soluble arsenic compounds in a water phase; and

separating the water phase containing the water-soluble arsenic compounds from the crude oil to obtain a treated crude oil having a reduced concentration of arsenic.

5. The method of any of claims 1 - 3, wherein the heavy metals comprise mercury.

6. The method of any of claims 1 - 4, wherein the effective amount of oxidizing agent for mixing into the crude oil is in a molar ratio of oxidizing agent to heavy metals of 5:1 to 20,000:1.

7. The method of any of claims 1 - 4, wherein the effective amount of oxidizing agent for mixing into the crude oil is in a molar ratio of oxidizing agent to heavy metals of 50:1 to 500:1.

8. The method any of claims 1 - 4, wherein the oxidizing agent is selected from the group of inorganic peracids and salts thereof, organic peracids and salts thereof, and mixtures thereof.

9. The method of claim 8, wherein the oxidizing agent is selected from the group of sodium perborate, potassium perborate, sodium carbonate perhydrate, potassium peroxymonosulfate, sodium peroxocarbonate, sodium peroxodicarbonate, and mixtures thereof.

10. The method of claim 9, wherein the oxidizing agent is potassium peroxymonosulfate.

11. The method of any of claims 1 - 3, wherein the treated crude oil contains less than 100 ppb heavy metals as mercury.

12. The method of any of claims 1 - 3, wherein the treated crude oil contains less than 10 ppb heavy metals as mercury.

13. The method of any of claims 1 - 4, wherein the treated crude oil contains less than 50 ppb arsenic.

14. The method of claim 13, wherein the treated crude oil contains less than 10 ppb arsenic.

15. The method of any of claims 1 - 4, for treating a crude oil having a specific gravity of at least 0.75 at 60°F.

16. The method of any of claims 1 - 2, wherein the oxidizing agent extracts heavy metals by converting the heavy metals to heavy metal cations in a water-oil emulsion.

17. The method of claim 2, wherein the water phase containing the soluble heavy metal compounds is formed by settling of oil phase and water phase in the water-oil emulsion.

18. The method of claim 2, wherein the water phase containing the soluble heavy metal compounds is formed within 20 minutes of adding the complexing agent.

19. The method of any of claims 17 - 18, wherein the water phase containing the soluble heavy metal compounds is formed without using mechanical or rotating means.

20. The method of claim 1, further comprising adding a complexing agent to the water-oil emulsion.

21. The method of any of claims 2-4 and 20, wherein the complexing agent is a metal halide.

22. The method of claim 21, wherein the complexing agent is KI.

23. The method of claim 2, wherein the addition of the complexing agent results in at least 50 mole % of the heavy metals being extracted from the water-oil emulsion into the water phase as soluble heavy metal compounds.

24. The method of claim 2, wherein the addition of the complexing agent results in at least 80% of the heavy metal being extracted into the water phase as soluble heavy metal compounds.

25. The method of claim 2, wherein the formation of soluble heavy metal compounds in the water phase occurs within 15 minutes of adding the complexing agent.

26. The method of any of claims 2, 3, 4, and 20, wherein the complexing agent is selected from the group of ethylenediamine, propylenediamine, triaminotriethylamine, diethylenetriamine, triethylenetetramine (TRIEN), tetra-2-aminoethylethlenediamine, tetraethylenepentamine (TETREN), sulfides, ammonium thiosulfate, alkali metal thiosulfates, alkaline earth metal thiosulfates, iron thiosulfates, alkali metal dithionites, and alkaline earth metal dithionites, and mixtures thereof.

27. A method for reducing a trace amount of mercury in a crude oil, comprising:

mixing into the crude oil an effective amount of an oxidizing agent selected from the group of sodium perborate, potassium perborate, sodium carbonate perhydrate, potassium peroxymonosulfate, sodium peroxocarbonate, sodium peroxodicarbonate, and mixtures thereof to extract at least a portion of the mercury into a water-oil emulsion;

separating a water phase containing the extracted mercury from the crude oil to obtain a treated crude oil having a reduced concentration of mercury.

28. The method of claim 27, wherein the oxidizing agent is potassium peroxymonosulfate.

29. The method of any of claims 27 - 28, wherein the water phase containing the extracted mercury is formed by settling of oil phase and water phase in the water-oil emulsion.

30. The method of claim 27, wherein the effective amount of oxidizing agent is in a molar ratio of oxidizing agent to mercury of 5:1 to 20,000:1.

31. The method of claim 27, wherein the effective amount of oxidizing agent is in a molar ratio of oxidizing agent to mercury of 50:1 to 500:1.

32. The method of claim 27, wherein the effective amount of oxidizing agent is mixed to the crude oil in an amount of water, with a volume ratio of water to crude oil ranging from 0.1:1 to 1:1.

33. The method of claim 27, wherein the water phase containing the extracted mercury from the crude oil is injected back to a reservoir.

34. A method for reducing a trace amount of mercury in a crude oil, comprising:

mixing into the crude oil an amount of at least an oxidizing agent selected from the group of oxyhalites, hydroperoxides, organic peroxides, inorganic peracids and salts thereof, organic peracids and salts thereof, ozone and combinations thereof to extract at least a portion of the mercury into a water-oil emulsion;

adding an amount of a complexing agent to convert the extracted mercury to soluble mercury compounds in a water phase; and

separating the water phase containing the soluble mercury compounds from the crude oil, leaving a treated crude oil having a reduced concentration of mercury.

35. The method of claim 34, for treating a crude oil having a specific gravity of at least 0.75 at 60°F.

36. The method of any of claims 34 - 35, wherein the complexing agent is a metal halide.

37. The method of any of claims 34 - 35, wherein the oxidizing agent is an oxygen containing compound selected from the group of oxyhalites, hydroperoxides, and organic peroxides, inorganic peracids and salts thereof, organic peracids and salts thereof, ozone, and combinations thereof.

38. The method of any of claims 34 - 35, wherein the oxidizing agent is selected from the group of sodium perborate, potassium perborate, sodium carbonate perhydrate, potassium peroxymonosulfate, sodium peroxocarbonate, sodium peroxodicarbonate, and mixtures thereof.

39. The method of any of claims 34 - 35, wherein the oxidizing agent is an oxyhalite.

40. The method of any of claims 34 - 35, wherein the oxidizing agent is NaOCl.

41. The method of any of claims 34 - 35, wherein the oxidizing agent is a ferrous halide.

42. The method of any of claims 34 - 35, wherein the oxidizing agent is $FeCl_2$.

43. The method of any of claims 34 - 35, wherein the oxidizing agent is potassium peroxymonosulfate.

44. The method of any of claims 34 - 35, wherein the addition of the complexing agent converts at least 50 mole % of the extracted mercury to soluble mercury compounds.

45. The method of any of claims 34 - 35, wherein the addition of the complexing agent converts at least 80 mole % of the extracted mercury to soluble mercury compounds.

46. The method of any of claims 34 - 35, wherein the complexing agent is a metal halide selected frown the group of K, Li, Na, Ca, Fe, Ni, and Zn.

47. The method of any of claims 34 - 35, wherein the complexing agent is selected from the group of sulfides, ammonium thiosulfate, alkali metal thiosulfates, alkaline earth metal thiosulfates, iron thiosulfates, alkali metal dithionites, alkaline earth metal dithionites, alkali metal peroxomonosulfate compounds, and mixtures thereof.

48. The method of any of claims 34 - 35, wherein the complexing agent is selected from the group of ethylenediamine, propylenediamine, triaminotriethylamine, diethylenetriamine, triethylenetetramine (TRIEN), tetra-2-aminoethylethlenediamine, tetraethylenepentamine (TETREN), sulfides, ammonium thiosulfate, alkali metal thiosulfates, alkaline earth metal thiosulfates, iron thiosulfates, alkali metal dithionites, and alkaline earth metal dithionites, and mixtures thereof.

49. The method of any of claims 34 - 35, wherein the complexing agent is KI.

50. The method of any of claims 34 - 35, wherein the treated crude oil contains less than 50 ppb heavy metals.

51. The method of any of claims 34 - 35, wherein the separation of the water phase containing soluble heavy metal compounds from the crude oil is without using mechanical or rotating means.

52. The method of any of claims 34 - 35, wherein the formation of soluble metal compounds in the water phase occurs 15 minutes after the addition of the complexing agent.

53. The method of any of claims 34 - 35, wherein at least 50% of the heavy metal are extracted and converted to soluble heavy metal compounds in the water phase.

54. In a method for treating a crude oil to reduce its mercury level, comprising adding to the crude oil a water stream consisting essentially of an oxidizing agent selected from the group of elemental halogens, halogen containing compounds, ozone, oxyhalites, hydroperoxides, and organic peroxides, inorganic peracids and salts thereof, organic peracids and salts thereof, to convert at least a portion of the mercury to mercury cations, and extracting at least a portion of the mercury cations into the water stream forming a mercury-rich wastewater, and separating the wastewater from the crude oil, leaving a treated crude oil having a reduced concentration of mercury, the improvement comprising:

adding a complexing agent to convert at least a portion of the mercury cations to soluble mercury compounds in a water phase prior to separating the water phase containing soluble mercury compounds from the crude oil, leaving a treated crude oil having a reduced mercury level.

55. The method of claim 54, wherein the oxidizing agent is an oxyhalite.

56. The method of claim 55, wherein the oxidizing agent is selected from NaOCl and $Ca(OCl)_2$ and mixtures thereof.

57. The method of claim 56, wherein the oxidizing agent is NaOCl.

58. The method of claim 54, wherein the oxidizing agent is ferrous halide.

59. The method of claim 54, wherein the oxidizing agent is sodium hypochlorite and the water stream comprising sodium hypochlorite has a pH of less than 6.

60. The method of claim 54, wherein the water stream has a pH of less than 5.

61. The method of claim 54, wherein the water stream has a pH of less than 3.

62. The method of claim 54, wherein the addition of the complexing agent results in at least 50 mole % of the mercury cations being converted to soluble mercury compounds.

63. The method of claim 54, wherein the addition of the complexing agent results in at least 80% of the mercury cations being converted to soluble mercury compounds.

64. The method of claim 54, wherein the complexing agent is a metal halide selected from the group of K, Na, Li, Ca, Fe, Ni, and Zn.

65. The method of claim 54, wherein the complexing agent is selected from the group of sulfides, ammonium thiosulfate, alkali metal thiosulfates, alkaline earth metal thiosulfates, iron thiosulfates, alkali metal dithionites, alkaline earth metal dithionites, alkali metal peroxomonosulfate compounds, and mixtures thereof.

66. The method of claim 54, wherein the complexing agent is selected from the group of ethylenediamine, propylenediamine, triaminotriethylamine, diethylenetriamine, triethylenetetramine (TRIEN), tetra-2-aminoethylethlenediamine, tetraethylenepentamine (TETREN), and mixtures thereof.

67. The method of claim 54, wherein the complexing agent is an inorganic sulfur compound selected from the group of sulfides, ammonium thiosulfate, alkali metal thiosulfates, alkaline earth metal thiosulfates, iron thiosulfates, alkali metal dithionites, and alkaline earth metal dithionites, and mixtures thereof.

68. The method of claim 54, wherein the treated crude oil contains less than 50 ppb mercury.

69. The method of claim 54, wherein the formation of a water phase containing soluble mercury compounds is carried out in a contact zone comprising at least one of a packed

tower, a bubble tray column, a stirred mixing tank, a fiber contactor, and a rotating disc contactor.

70. The method of claim 54, wherein the formation of a water phase containing soluble mercury compounds occurs within 15 minutes of the addition of water stream consisting essentially of an oxidizing agent to the crude oil.

71. The method of claim 54, wherein at least 50% of the mercury cations are converted to soluble mercury compounds.

72. The method of claim 54, wherein the crude oil is contacted with the water stream consisting essentially of an oxidizing agent in a contact zone comprising fibers, forming an admixture of mercury-rich wastewater that flows over and along the fibers.

73. A method for reducing a trace amount of arsenic in a crude oil, comprising:

mixing into the crude oil an amount of at least an oxidizing agent selected from the group of oxyhalites, hydroperoxides, organic peroxides, inorganic peracids and salts thereof, organic peracids and salts thereof, ozone and combinations thereof to extract at least a portion of arsenic into a water-oil emulsion as arsenic cations, forming a mixture;

adding a sufficient amount of acid to the water-oil emulsion mixture for a pH of 5.5 or less

adding an effective amount of a complexing agent to the water-oil emulsion mixture to convert the arsenic cations to soluble arsenic compounds in a water phase; and

separating the water phase containing the soluble arsenic compounds from the crude oil, leaving a treated crude oil having a reduced concentration of arsenic.

74. The method of claim 73, wherein the acid is added to the crude oil at any time prior to the addition of the oxidizing agent, concurrent with the addition of the oxidizing agent, prior to the addition of the complexing agent, or concurrent with the addition of the complexing agent.

75. The method of any of claims 73 - 74, wherein adding an amount of a complexing agent comprises adding a complexing agent selected from metal halides, sulfur compounds, and mixtures thereof.

76. The method of any of claims 73 - 74, wherein adding an amount of a complexing agent comprises adding at least a metal halide.

77. The method of any of claims 73 - 74, wherein adding an amount of a complexing agent comprises adding at least a metal halide selected from halides of Li, Na, K, Ca, Cu, Ni, Fe, Zn, Ba, Sr, Ag, and combinations thereof.

78. The method of any of claims 73 - 74, wherein adding an amount of a complexing agent comprises adding ferric chloride or cupric chloride.

79. The method of any of claims 73 - 74, wherein adding an amount of a complexing agent comprises adding at least a sulfur compound selected from the group of sulfides, thiosulfates, dithionites, and mixtures thereof.

80. The method of any of claims 73 - 74, wherein adding an amount of a complexing agent comprises adding at least a complexing agent selected from the group of sodium polysulfide, ammonium thiosulfate, alkali metal thiosulfates, alkaline earth metal thiosulfates, iron thiosulfates, alkali metal dithionites, alkaline earth metal dithionites, and mixtures thereof.

81. The method of any of claims 73 - 74, wherein adding an amount of a complexing agent comprises adding at least a complexing agent selected from the group of potassium sulfide, sodium polysulfide, sodium thiosulfate, potassium peroxomonosulfate, and mixtures thereof.

82. The method of any of claims 73 - 74, wherein mixing into the crude oil an amount of at least an oxidizing agent comprises adding at least an oxidizing agent selected from the group of molecular halogen, iodine (I_2), oxyhalites, hypochlorites, and mixtures thereof.

83. The method of any of claims 73 - 74, wherein the addition of the complexing agent occurs either before, simultaneously with, or after the addition of the oxidizing agent to the crude oil.

84. The method of any of claims 73 - 74, wherein the addition of the complexing agent results in at least 50 mole % of the arsenic cations being converted to soluble arsenic compounds.

85. The method of any of claims 73 - 74, wherein the addition of the complexing agent results in at least 80% of the arsenic cations being converted to soluble mercury compounds.

86. The method of claim 1, wherein the crude oil feed is mixed with the oxidizing agent in a contact zone comprising at least one of a packed tower, a bubble tray column, a stirred mixing tank, a fiber contactor, and a rotating disc contactor.

87. The method of claim 1, wherein the treated crude oil contains less than 50 ppb arsenic.

88. The method of claim 1, wherein the formation of a water phase containing soluble arsenic compounds occurs within 15 minutes of the addition of the oxidizing agent to the crude oil.

89. A method for reducing a trace amount of arsenic in a crude oil, comprising:

mixing into the crude oil an amount of at least an oxidizing agent selected from the group of oxyhalites, hydroperoxides, organic peroxides, inorganic peracids and salts thereof, organic peracids and salts thereof, ozone and combinations thereof to extract at least a portion of arsenic into a water-oil emulsion as arsenic cations, forming a mixture;

adding a sufficient amount of acid for the water-oil emulsion to have a pH of 5.5 or less;

adding an amount of a complexing agent selected from the group of metal halides and sulfur compounds to the water-oil emulsion mixture to convert the arsenic cations as As^{5+} and As^{3+} to soluble arsenic compounds in a water phase; and

separating the water phase containing the soluble arsenic compounds from the crude oil, leaving a treated crude oil having a reduced concentration of arsenic.

90. A method for reducing a trace amount of arsenic in a crude oil, comprising:

contacting the crude oil with a water stream containing an oxidizing agent to form a water-oil emulsion, the water stream has a pH of 6 or less;

adding an amount of a complexing agent to the water-oil emulsion to form soluble arsenic compounds in a water phase; and

separating the water phase containing the soluble arsenic compounds from the crude oil, leaving a treated crude oil having a reduced concentration of arsenic.

91. The method of claim 20, wherein the crude oil is contacted with the treatment solution in a contact zone comprising fibers and wherein the contact of the crude oil with the treatment solution forms an admixture containing a crude oil and water that flows over and along the fibers.

CLAIMS

1. A method for reducing a trace amount of heavy metals in a crude oil, comprising:

mixing into the crude oil an effective amount of at least an oxidizing agent selected from the group of hydroperoxides, organic peroxides, inorganic peracids and salts thereof, organic peracids and salts thereof, molecular halogens, ozone and combinations thereof to extract at least a portion of the heavy metals in a water oil emulsion;

separating the extracted heavy metals from the crude oil to obtain a treated crude oil having a reduced concentration of heavy metals;

wherein the heavy metals comprise any of mercury, arsenic and combinations thereof.

2. The method of claim 1, prior to separating the extracted heavy metals from the crude oil, further comprising;

adding an effective amount of a complexing agent to convert at least a portion of the extracted heavy metals in the water oil emulsion to soluble heavy metal compounds in a water phase; and

separating the water phase containing the soluble heavy metal compounds from the crude oil to obtain a treated crude oil having a reduced concentration of heavy metals.

3. The method of claim 1, wherein the oxidizing agent is selected from the group of sodium perborate, potassium perborate, sodium carbonate perhydrate, potassium peroxymonosulfate, sodium peroxocarbonate, sodium peroxodicarbonate, and mixtures thereof.

4. The method of any of claims 1 - 3, wherein the effective amount of oxidizing agent for mixing into the crude oil is in a molar ratio of oxidizing agent to heavy metals of 5:1 to 20,000:1.

5. The method of claim 2, wherein the water phase containing the soluble heavy metal compounds is formed within 20 minutes of adding the complexing agent.

6. The method of claim 2, wherein the complexing agent is a metal halide.

7. The method of any of claims 2, 5, and 6, wherein the addition of the complexing agent results in at least 50 mole % of the heavy metals being extracted from the water-oil emulsion into the water phase as soluble heavy metal compounds.

8. The method of any of claims 2, 5, and 6, wherein the complexing agent is selected from the group of ethylenediamine, propylenediamine, triaminotriethylamine, diethylenetriamine, triethylenetetramine (TRIEN), tetra-2-aminoethylethlenediamine, tetraethylenepentamine (TETREN), sulfides, ammonium thiosulfate, alkali metal thiosulfates, alkaline earth metal thiosulfates, iron thiosulfates, alkali metal dithionites, and alkaline earth metal dithionites, and mixtures thereof.

9. The method of any of claims 1-3, wherein the effective amount of oxidizing agent is mixed to the crude oil in an amount of water, with a volume ratio of water to crude oil ranging from 0.1:1 to 1:1.

10. The method of claim 2, further comprising injecting the water phase containing the soluble heavy metal compounds into a reservoir.

11. A method for reducing a trace amount of mercury in a crude oil, comprising:

mixing into the crude oil an amount of at least an oxidizing agent selected from the group of oxyhalites, hydroperoxides, organic peroxides, inorganic peracids and salts thereof, organic peracids and salts thereof, ozone and combinations thereof to extract at least a portion of the mercury into a water-oil emulsion;

adding an amount of a complexing agent to convert the extracted mercury to soluble mercury compounds in a water phase; and

separating the water phase containing the soluble mercury compounds from the crude oil, leaving a treated crude oil having a reduced concentration of mercury.

12. The method of claim 11, wherein the complexing agent is a metal halide.

13. The method of any of claims 11-12, wherein the oxidizing agent is an oxygen containing compound selected from the group of oxyhalites, hydroperoxides, and organic peroxides, inorganic peracids and salts thereof, organic peracids and salts thereof, ozone, and combinations thereof.

14. The method of any of claims 11-12, wherein the addition of the complexing agent converts at least 50 mole % of the extracted mercury to soluble mercury compounds, and the complexing agent is selected from the group of sulfides, ammonium thiosulfate, alkali metal thiosulfates, alkaline earth metal thiosulfates, iron thiosulfates, alkali metal dithionites, alkaline earth metal dithionites, alkali metal peroxomonosulfate compounds, ethylenediamine, propylenediamine, triaminotriethylamine, diethylenetriamine, triethylenetetramine (TRIEN), tetra-2-aminoethylethlenediamine, tetraethylenepentamine (TETREN), sulfides, ammonium thiosulfate, alkali metal thiosulfates, alkaline earth metal thiosulfates, iron thiosulfates, alkali metal dithionites, and alkaline earth metal dithionites, and mixtures thereof.

15. The method of any of claims 11-12, wherein the oxidizing agent is selected from oxyhalites, ferrous halide, potassium peroxymonosulfate, and combinations thereof, and the complexing agent is a metal halide selected frown the group of K, Li, Na, Ca, Fe, Ni, and Zn, and wherein the formation of soluble metal compounds in the water phase occurs 15 minutes after the addition of the complexing agent.

16. In a method for treating a crude oil to reduce its mercury level, comprising adding to the crude oil a water stream consisting essentially of an oxidizing agent selected from the group of elemental halogens, halogen containing compounds, ozone, oxyhalites, hydroperoxides, and organic peroxides, inorganic peracids and salts thereof, organic peracids and salts thereof, to convert at least a portion of the mercury to mercury cations, and extracting at least a portion of the mercury cations into the water stream forming a mercury-rich wastewater, and separating the wastewater from the crude oil, leaving a treated crude oil having a reduced concentration of mercury, the improvement comprising:

adding a complexing agent to convert at least a portion of the mercury cations to soluble mercury compounds in a water phase prior to separating the water phase containing soluble

mercury compounds from the crude oil, leaving a treated crude oil having a reduced mercury level.

17. The method of claim 16, wherein the oxidizing agent is selected from NaOCl, $Ca(OCl)_2$, ferrous halide and mixtures thereof.

18. The method of any of claims 16 - 17, wherein the addition of the complexing agent results in at least 50 mole % of the mercury cations being converted to soluble mercury compounds.

19. The method of any of claims 16 - 17, wherein the complexing agent is a metal halide selected from the group of K, Na, Li, Ca, Fe, Ni, and Zn.

20. The method of any of claims 16 - 17, wherein the complexing agent is selected from the group of sulfides, ammonium thiosulfate, alkali metal thiosulfates, alkaline earth metal thiosulfates, iron thiosulfates, alkali metal dithionites, alkaline earth metal dithionites, alkali metal peroxomonosulfate compounds, ethylenediamine, propylenediamine, triaminotriethylamine, diethylenetriamine, triethylenetetramine (TRIEN), tetra-2-aminoethylethlenediamine, tetraethylenepentamine (TETREN), an inorganic sulfur compound selected from the group of sulfides, ammonium thiosulfate, alkali metal thiosulfates, alkaline earth metal thiosulfates, iron thiosulfates, alkali metal dithionites, and alkaline earth metal dithionites, and mixtures thereof.