

What is Claimed:

1. A modified clay sorbent for sorbing PFAS compounds from a contaminated sample, comprising:

a clay intercalated with one or more multifunctional-quaternary amine compounds having a functionality of 3 or more and one or more mono-quaternary amine compounds.

2. The modified clay sorbent of claim 1, wherein the clay is intercalated with the one or more multifunctional-quaternary amine compounds and one or more mono-quaternary amine compounds to at least 50% of the a total cationic exchange capacity of the clay.

3. A modified clay sorbent for sorbing PFAS compounds from a contaminated sample, comprising:

a first modified clay comprising a clay intercalated with the one or more mono-quaternary amine compounds; and

a second modified clay comprising a clay intercalated with the one or more multifunctional-quaternary amine compounds having a functionality of 3 or more.

4. The modified clay sorbent of any one of the preceding claims, wherein the one or more multifunctional-quaternary amine compounds are present in a mole percent of at least about 20 mol% based on the total moles of quaternary amine compounds present in the modified clay sorbent.

5. The modified clay sorbent of claim 4, wherein the one or more multifunctional-quaternary amine compounds are present in a mole percent of about 20 mol% to about 80 mol% based on the total moles of quaternary amine compound present in the modified clay sorbent.

6. The modified clay sorbent of claim 4, wherein the one or more multifunctional-quaternary amine compounds are present in a mole percent of greater than about 60 mol% to about 95 mol% based on total moles of quaternary amine compounds present in the modified clay sorbent

7. The modified clay sorbent of any one of claims 3 to 6, wherein the first modified clay and the second modified clay are each intercalated with the respective one or more mono-quaternary amine compounds and multifunctional-quaternary amine compounds to at least about 50% of the cationic exchange capacity of the respective first or second modified clay.

8. The modified clay sorbent of any one of the preceding claims, wherein the one or more multifunctional-quaternary amine compounds have 18 or more carbons.

9. The modified clay sorbent of any one of the preceding claims, wherein the clay is one or more of attapulgite, bentonite, montmorillonite, nontronite, beidellite, volkonskoite, hectorite, saponite, sauconite, sobockite, stevensite, svinfordite, vermiculite, palygorskite, kalonite, and sepiolite.

10. The modified clay sorbent of any one of the preceding claims, wherein the modified clay sorbent is present in a mat.

11. The modified clay sorbent of any one of the preceding claims, wherein the mono-functional quaternary amine is one or more of dimethyl di(C14-C18 alkyl) ammonium chloride.

12. A kit comprising: the modified clay sorbent of any one of the preceding claims and instructions for adding the clay sorbent to a contaminated sample for sorption of PFAS compounds.

13. A kit comprising:

the modified clay sorbent of claim 3, wherein the first and second modified clays are present as separate components, and

instructions for adding the first modified clay and the second modified clay individually to a contaminated sample to form the modified clay sorbent in amounts such that the one or more multifunctional-quaternary amine compounds are present in an amount of 20 mol% to about 80 mol% based on the total moles of quaternary amine compounds added to the sample.

14. The kit of claim 13, wherein the first and second modified clays are added in amounts such that the one or more multifunctional-quaternary amine compounds are present in an amount of 20 mol% to about 80 mol% based on the total moles of quaternary amine compounds added to the sample.

15. The kit of claim 13 or 14, wherein the first and second modified clays are added substantially simultaneously.

16. The kit of claim 13 or 14, wherein the first and second modified clays are added sequentially.

17. A method of sorbing PFAS compounds from a contaminated sample, comprising: admixing a modified clay sorbent with the sample, wherein the modified clay sorbent comprises a clay intercalated with a one or more mono-quaternary amine compounds and one or more multifunctional-quaternary amine compounds having a functionality of 3 or more.

18. A method of sorbing PFAS compounds from a contaminated sample, comprising: admixing a clay, one or more mono-quaternary amine compounds, and one or more multifunctional-quaternary amine compounds with the sample, wherein the clay is intercalated with the one or more mono-quaternary amine compounds and the one or more multifunctional-quaternary amine compounds *in situ* to form a modified clay sorbent for sorbing PFAS compounds from the contaminated sample.

19. The method of claim 17 or 18, wherein the one or more multifunctional-quaternary amine compounds are present in an amount of at least about 20 mol% based on the total moles of the quaternary amine compounds in the modified clay sorbent.

20. The method of any one of claims 17 to 19, wherein the one or more multifunctional-quaternary amine compounds are present in an amount of about 20 mol% to about 80 mol% based on the total moles of quaternary amine compound in the modified clay sorbent.

21. A method of sorbing PFAS compounds from a contaminated sample, comprising: admixing a modified clay sorbent with the sample, wherein the modified clay sorbent comprises a first modified clay comprising a clay intercalated with a one or more mono-quaternary amine compounds and a second modified clay comprising a clay intercalated with one or more multifunctional-quaternary amine compounds having a functionality of 3 or more.

22. The method of claim 21, wherein a ratio of an amount of the first modified clay to the amount of the second modified clay is selected such that the one or more multifunctional-quaternary amine compounds are present in an amount of about 20 mol% to about 80 mol% based on the total moles of the quaternary amine compounds admixed with the sample.

23. The method of claim 21, wherein each of the first modified clay and the second modified clay are intercalated to a cationic exchange capacity of the clay of at least 50%.

24. The method of claim 21 or 22, wherein the first and second modified clays are pre-blended in the modified clay sorbent such that the one or more multifunctional-quaternary amine compounds are present in an amount of about 20 mol% to about 80 mol% based on the total moles of the quaternary amine compounds in the modified clay sorbent blend and the first and second modified clays are admixed with the sample as a single composition.

25. The method of claim 21 or 22, wherein admixing the modified clay sorbent with the sample comprises separately adding the first modified clay and the second modified clay to the sample in amounts such that the one or more multifunctional-quaternary amine compounds

are present in an amount of about 20 mol% to about 80 mol% based on the total moles of the quaternary amine compounds admixed with the sample.

26. The method of claim 25 wherein the first and second modified clays are added simultaneously.

27. The method of claim 25, wherein the first and second modified clays are added sequentially.

28. The method of any one of claims 17 to 27, wherein the one or more multifunctional-quaternary amine compounds comprises at least 18 carbons.

29. The method of any one of claims 17 to 27, wherein the one or more multifunctional-quaternary amine compounds are present in an amount of about 20 mol% to about 80 mol% based on the total moles of quaternary amine compounds in the modified clay sorbent.

30. The method of any one of claims 17 to 29, wherein the clay is one or more of attapulgite, bentonite, montmorillonite, nontronite, beidellite, volkonskoite, hectorite, sapponite, sauconite, sobockite, stevensite, svinfordite, vermiculite, palygorskite, kalonite, and sepiolite.

31. The method of any one of claims 17 to 30, where the sorbent is capable of adsorbing at least 0.2 milligrams of PFAS compounds per gram of modified clay sorbent.

32. The method of any one of claims 17 to 31, wherein the sample is a contaminated soil, and the method comprises mixing the contaminated soil and the modified clay sorbent such that the modified clay sorbent is present in an amount of greater than about 0.5 wt% of the modified clay sorbent in the mixture.

33. The method of any one of claims 17 to 32, wherein the sample is a contaminated waste water stream, and the method comprises admixing the modified clay sorbent and the contaminated water stream by passing the contaminated water through a bed of the modified clay sorbent at a flow rate to maintain a contact time of the contaminated water with the bed of at least about 1 minute.

34. The method of any one of claims 17 to 32, wherein the modified clay sorbent is in the form of a prepacked permeable mat or gabion.

35. The method of any one of claims 17 to 32, wherein the modified clay sorbent is in a granular or powder form into a body of water such that the modified clay forms a permeable reactive barrier layer.

36. The method of any one of claims 17 to 32, comprising the treatment of PFAS compounds from a contaminated water stream by mixing the modified clay and contaminated water in a tank.

37. The method of any one of claims 17 to 32, comprising the treatment of PFAS compounds from a contaminated water stream by injecting a suspension of the modified clay into contaminated soil and or a contaminated groundwater plume.

38. The method of any one of claims 17 to 37, wherein the contaminated sample is wastewater.

39. The method of any one of claims 17 to 37, wherein the contaminated sample is ground water.

40. A modified clay sorbent for sorbing PFAS compounds from a contaminated sample, comprising:

a clay intercalated with one or more trifunctional-quaternary amine compounds having and one or more mono-quaternary amine compounds.

41. The modified clay sorbent of claim 40, wherein the one or more trifunctional-quaternary amine compounds are present in a mole percent of about 25 mol% to about 95 mol% based on total moles of quaternary amine compounds present in the modified clay sorbent.

42. The modified clay sorbent of claim 40 or 41, wherein the clay is intercalated with the one or more trifunctional-quaternary amine compounds and one or more mono-quaternary amine compounds to at least 50% of the a total cationic exchange capacity of the clay.

43. A modified clay sorbent for sorbing PFAS compounds from a contaminated sample, comprising:

a first modified clay comprising a clay intercalated with the one or more mono-quaternary amine compounds; and

a second modified clay comprising a clay intercalated with the one or more trifunctional-quaternary amine compounds.

44. The modified clay sorbent of claim 43, wherein second modified clay is present in the modified clay sorbent in an amount such that the one or more trifunctional-quaternary amine compounds are present in an amount of about 25 mol% to about 95 mol% based on total moles of quaternary amine compounds present in the modified clay sorbent

45. The modified clay sorbent of claim 43 or 44, wherein the first modified clay and the second modified clay are each intercalated with the respective one or more mono-quaternary amine compounds and trifunctional-quaternary amine compounds to at least about 50% of the cationic exchange capacity of the respective first or second modified clay.

46. The modified clay sorbent of claims 40-45, wherein the trifunctional-quaternary amine compounds have 18 or more carbons.

47. The modified clay sorbent of any one of claims 40 to 46, wherein the trifunctional-quaternary amine compound is present in an amount of at least 20 mol% based on the total moles of quaternary amine compound in the modified clay sorbent.

48. The modified clay sorbent of claim 47, wherein the trifunctional-quaternary amine compound is present in an amount of about 20 mol% to about 80 mol% based on the total moles of quaternary amine compound in the modified clay sorbent.

49. The modified clay sorbent of claim 47, wherein the trifunctional-quaternary amine compound is present in an amount of greater than 60 mol%.

50. The modified clay sorbent of any one claim 40 to 49, wherein the clay is one or more of attapulgite, bentonite, montmorillonite, nontronite, beidellite, volkonskoite, hectorite, saponite, sauconite, sobockite, stevensite, svinfordite, vermiculite, palygorskite, kalonite, and sepiolite.

51. The modified clay sorbent of any one of claims 40 to 50, wherein the modified clay sorbent is present in a mat.

52. The modified clay sorbent of any one of claims 50 to 51, wherein the mono-functional quaternary amine is one or more of dimethyl di(C14-C18 alkyl) ammonium chloride.

53. A kit comprising: the modified clay sorbent of any one of claims 40 to 52 and instructions for adding the clay sorbent to a contaminated sample for sorption of PFAS compounds.

54. A kit comprising:

the modified clay sorbent of claim 43, wherein the first and second modified clays are present as separate components, and

instructions for adding the first modified clay and the second modified clay individually to a contaminated sample to form the modified clay sorbent in amounts such that the one or more

trifunctional-quaternary amine compounds are present in an amount of at least about 20 mol% based on the total moles of quaternary amine compounds added to the sample.

55. The kit of claim 54, wherein the first and second modified clays are added in amounts such that the one or more trifunctional-quaternary amine compounds are present in an amount of 20 mol% to about 80 mol% based on the total moles of quaternary amine compounds added to the sample.

56. The kit of claim 54 or 55, wherein the first and second modified clays are added substantially simultaneously.

57. The kit of claim 54 or 55, wherein the first and second modified clays are added sequentially.

58. A method of sorbing PFAS compounds from a contaminated sample, comprising:

admixing a modified clay sorbent with the sample, wherein the modified clay sorbent comprises a clay intercalated with one or more trifunctional-quaternary amine compounds.

59. A method of sorbing PFAS compounds from a contaminated sample, comprising: admixing a modified clay sorbent with the sample, wherein the modified clay sorbent comprises a clay intercalated with a one or more mono-quaternary amine compounds and one or more trifunctional-quaternary amine compounds.

60. A method of sorbing PFAS compounds from a contaminated sample, comprising: admixing a clay, one or more mono-quaternary amine compounds, and one or more trifunctional-quaternary amine compounds with the sample, wherein the clay is intercalated with the one or more mono-quaternary amine compounds and the one or more trifunctional-quaternary amine compounds *in situ* to form a modified clay sorbent for sorbing PFAS compounds from the contaminated sample.

61. The method of any one of claims 58 to 60, wherein the one or more trifunctional-quaternary amine compounds are present in an amount of at least about 20 mol% based on the total moles of the quaternary amine compounds in the modified clay sorbent.

62. The method of claim 61, wherein the one or more trifunctional-quaternary amine compounds are present in an amount of about 20 mol% to about 80 mol% based on the total moles of the quaternary amine compounds in the modified clay sorbent.

63. The method of any one of claims 58 to 62, wherein the clay is intercalated with the one or more trifunctional-quaternary amine compounds and one or more mono-quaternary amine compounds to at least 50% of the a total cationic exchange capacity of the clay.

64. A method of sorbing PFAS compounds from a contaminated sample, comprising: admixing a modified clay sorbent with the sample, wherein the modified clay sorbent comprises a first modified clay comprising a clay intercalated with a one or more mono-quaternary amine compounds and a second modified clay comprising a clay intercalated with one or more trifunctional-quaternary amine compounds.

65. The method of claim 64, wherein a ratio of an amount of the first modified clay to the amount of the second modified clay is selected such that the trifunctional-quaternary amine compounds are present in an amount of at least about 20 mol% based on the total moles of the quaternary amine compounds admixed with the sample.

66. The method of claim 65, wherein each of the first modified clay and the second modified clay are intercalated to a cationic exchange capacity of the clay of at least 50%.

67. The method of any one of claims 64 or 66, wherein the first and second modified clays are pre-blended in the modified clay sorbent such that the one or more trifunctional-quaternary amine compounds are present in an amount of about 20 mol% to about 80 mol% based on the total moles of the quaternary amine compounds in the modified clay sorbent blend and the first and second modified clays are admixed with the sample as a single composition.

68. The method of any one of claims 64 to 66, wherein admixing the modified clay sorbent with the sample comprises separately adding the first modified clay and the second modified clay to the sample in amounts such that the one or more trifunctional-quaternary amine compounds are present in an amount of about 20 mol% to about 80 mol% based on the total moles of the quaternary amine compounds admixed with the sample.

69. The method of claim 68, wherein the first and second modified clays are added simultaneously.

70. The method of claim 68, wherein the first and second modified clays are added sequentially.

71. The method of any one of claims 58 to 70, wherein the one or more trifunctional-quaternary amine compounds comprises at least 18 carbons.

72. The method of any one of claims 59 to 71, wherein the one or more trifunctional-quaternary amine compounds are present in an amount of about 20 mol% to about 80 mol% based on the total moles of quaternary amine compounds in the modified clay sorbent.

73. The method of any one of claims 58 to 72, wherein the clay is one or more of attapulgite, bentonite, montmorillonite, nontronite, beidellite, volkonskoite, hectorite, sapponite, sauconite, sobockite, stevensite, svinfordite, vermiculite, palygorskite, kalonite, and sepiolite.

74. The method of any one of claims 58 to 73, where the sorbent is capable of adsorbing at least 0.2 milligrams of PFAS compounds per gram of modified clay sorbent.

75. The method of any one of claims 58 to 74, wherein the sample is a contaminated soil, and the method comprises mixing the contaminated soil and the modified clay sorbent such that the modified clay sorbent is present in an amount of greater than about 0.5 wt% of the modified clay sorbent in the mixture.

76. The method of any one of claims 58 to 75, wherein the sample is a contaminated waste water stream, and the method comprises admixing the modified clay sorbent and the contaminated water stream by passing the contaminated water through a bed of the modified clay sorbent at a flow rate to maintain a contact time of the contaminated water with the bed of at least about 1 minute.

77. The method of any one of claims 58 to 76, wherein the modified clay sorbent is in the form of a prepacked permeable mat or gabion.

78. The method of any one of claims 58 to 76, wherein the modified clay sorbent is in a granular or powder form into a body of water such that the modified clay forms a permeable reactive barrier layer.

79. The method of any one of claims 58 to 76, comprising the treatment of PFAS compounds from a contaminated water stream by mixing the modified clay and contaminated water in a tank.

80. The method of any one of claims 58 to 76, comprising the treatment of PFAS compounds from a contaminated water stream by injecting a suspension of the modified clay into contaminated soil and or a contaminated groundwater plume.

81. The method of any one of claims 58 to 80, wherein the contaminated sample is wastewater.

82. The method of any one of claims 58 to 80, wherein the contaminated sample is ground water.