

CLAIMS

1. A method of removing or reducing ~~the an~~ amount of boron present in an aqueous solution, wherein the boron exists in a form of ~~boric acid (H_3BO_3) or borate ions ($B(OH)_4^-$, $B_4O_7^{2-}$, $H_3BO_2^-$)~~ in the aqueous solution, the method comprising:

 contacting a boron removal medium with the aqueous solution, wherein the boron removal medium comprises graphene oxide, a carbon-based material comprising at least two ~~one~~ hydroxyl groups directly covalently bonded to the graphene oxide, and at least one a pyridinic nitrogen directly covalently bonded to the graphene oxide, or pyrrolic nitrogen, or graphitic nitrogen, or amine group; and

 separating the boron removal medium from the aqueous solution.
2. ~~The method according to claim 1, wherein the carbon-based material comprises at least two hydroxyl group and at least one pyridinic nitrogen, or pyrrolic nitrogen, or graphitic nitrogen, or amine group.~~
3. ~~The method according to claim 1, wherein the carbon-based material comprises at least four hydroxyl group and at least one pyridinic nitrogen, or pyrrolic nitrogen, or graphitic nitrogen, or amine group.~~
4. ~~The method according to any one of claims 1-3, wherein the carbon-based material comprises at least one of graphene, graphite, graphene oxide, carbon nanotube, activated carbon, lonsdaleite, fullerene, carbon fibre, carbon black, charcoal, and amorphous carbon.~~
5. ~~The method according to claim 4, wherein the carbon-based material is doped.~~
6. ~~The method according to claim 5, wherein the carbon-based material is nitrogen-doped.~~
7. ~~The method according to claim 6, wherein the carbon-based material comprises nitrogen-doped graphene oxide.~~
8. ~~The method according to claim 7, wherein the carbon-based material comprises nitrogen-doped reduced graphene oxide.~~

9. ~~The method according to any one of claims 1-8, wherein the at least one hydroxyl group and at least one pyridinic nitrogen, or pyrrolic nitrogen, or graphitic nitrogen, or amine group of the carbon-based material are directly covalently bound to the carbon-based material.~~
10. ~~The method according to any one of claims 1-8, wherein the at least one hydroxyl group and at least one pyridinic nitrogen, or pyrrolic nitrogen, or graphitic nitrogen, or amine group of the carbon-based material are covalently bound to the carbon-based material via a linker small molecule.~~
11. ~~The method according to any one of claims 1-8, wherein either the at least one hydroxyl group or the at least one pyridinic nitrogen, or pyrrolic nitrogen, or graphitic nitrogen, or amine group of the carbon-based material is covalently bound to the carbon-based material via a linker small molecule.~~
12. ~~The method according to any one of claims 1-11~~ claim 1, wherein the separating comprises centrifuging or filtering the ~~aqueous solution, or the separating comprises passing water through the boron removal medium~~ from the aqueous solution.
13. ~~A boron removal medium for use in removing or reducing the amount of boron present in an aqueous solution, wherein the boron exists in a form of boric acid (H_3BO_3) or borate ions ($\text{B}(\text{OH})_4^-$, $\text{B}_4\text{O}_7^{2-}$, H_3BO_2^-) in the aqueous solution, wherein the boron removal medium comprises a carbon-based material comprising at least one hydroxyl group and at least one pyridinic nitrogen, or pyrrolic nitrogen, or graphitic nitrogen, or amine group.~~
14. ~~The boron removal medium according to claim 13, wherein the carbon-based material comprises at least two hydroxyl group and at least one pyridinic nitrogen, or pyrrolic nitrogen, or graphitic nitrogen, or amine group.~~
15. ~~The boron removal medium according to claim 13, wherein the carbon-based material comprises at least four hydroxyl group and at least one pyridinic nitrogen, or pyrrolic nitrogen, or graphitic nitrogen, or amine group.~~

16. ~~The boron removal medium according to any one of claims 13-15, wherein the carbon-based material comprises at least one of graphene, graphite, graphene oxide, carbon nanotube, activated carbon, lonsdaleite, fullerene, carbon fibre, carbon black, charcoal, and amorphous carbon.~~
17. ~~The boron removal medium according to claim 16, wherein the carbon-based material is doped.~~
18. ~~The boron removal medium according to claim 17, wherein the carbon-based material is nitrogen-doped.~~
19. ~~The boron removal medium according to claim 18, wherein the carbon-based material comprises nitrogen-doped graphene oxide.~~
20. ~~The boron removal medium according to claim 19, wherein the carbon-based material comprises nitrogen-doped reduced graphene oxide.~~
21. ~~The boron removal medium according to any one of claims 13-20, wherein the at least one hydroxyl group and at least one pyridinic nitrogen, or pyrrolic nitrogen, or graphitic nitrogen, or amine group of the carbon-based material are directly covalently bound to the carbon-based material.~~
22. ~~The boron removal medium according to any one of claims 13-20, wherein the at least one hydroxyl group and at least one pyridinic nitrogen, or pyrrolic nitrogen, or graphitic nitrogen, or amine group of the carbon-based material are covalently bound to the carbon-based material via a linker small molecule.~~
23. ~~The boron removal medium according to any one of claims 13-20, wherein either the at least one hydroxyl group or the at least one pyridinic nitrogen, or pyrrolic nitrogen, or graphitic nitrogen, or amine group of the carbon-based material is covalently bound to the carbon-based material via a linker small molecule.~~
24. ~~A method of forming a boron removal medium for use in removing or reducing the amount of boron present in an aqueous solution, wherein the boron exists in a form of boric acid (H_3BO_3) or borate ions ($\text{B}(\text{OH})_4^-$, $\text{B}_4\text{O}_7^{2-}$, H_3BO_2^-) in the aqueous solution,~~

~~wherein the boron removal medium comprises a nitrogen-doped graphene oxide, the method comprising:~~

~~oxidizing graphite to graphene oxide; and~~

~~doping the graphene oxide with ammonia.~~

~~25. The method according to claim 24, wherein the boron removal medium comprises a nitrogen-doped graphene oxide comprising at least one hydroxyl group and at least one pyridinic nitrogen, or pyrrolic nitrogen, or graphitic nitrogen, or amine group.~~

~~26. The method according to claim 25, wherein the at least one hydroxyl group comes from the oxidation of carbon materials.~~

~~27. The method according to claim 25, wherein the at least one hydroxyl group comes from the transformation of a function group, preferably a carboxyl group, or carbonyl group.~~

~~28. The method according to claim 25, wherein the at least one hydroxyl group comes from another small molecule comprising a hydroxyl group coupled to a carbon material.~~

~~29. The method according to any one of claims 24-28, wherein the nitrogen doping comes from the hydrothermal treatment of carbon materials with ammonia in an autoclave.~~

~~30. The method according to any one of claims 24-28, wherein the nitrogen doping comes from ammonia or nitrogen plasma treatment of carbon materials.~~

~~31. The method according to any one of claims 24-28, wherein the nitrogen doping comes from a direct synthesis of nitrogen doping of carbon materials.~~

~~32. The method according to any one of claims 24-28, wherein the nitrogen doping comes from N^+ ion irradiated carbon materials.~~

~~33. The method according to any one of claims 24-28, wherein the nitrogen doping comes from a thermal treatment of carbon materials with ammonia.~~

~~34. The method according to any one of claims 24-28, wherein the nitrogen doping comes from a chemical treatment of carbon materials, preferably hydrazine, or other small molecule with nitrogen or amine group coupled to a carbon material.~~

35. ~~A method of regenerating a used boron removal medium according to any one of claims 13-23, comprising:~~
- ~~contacting the used boron removal medium with an acid; and~~
 - ~~rinsing the used boron removal medium with deionized water.~~
36. ~~The method according to claim 35, wherein the acid is sulfuric acid (H_2SO_4) or hydrochloric acid (HCl).~~
37. ~~A method of detecting and quantifying the amount of boron present in an aqueous solution, wherein the boron exists in a form of boric acid (H_3BO_3) or borate ions ($\text{B}(\text{OH})_4^-$, $\text{B}_4\text{O}_7^{2-}$, H_3BO_2^-) in the aqueous solution, the method comprising:~~
- ~~contacting a boron removal medium of any one of claims 13 to 23 with a first sample of the aqueous solution to remove boron;~~
 - ~~contacting a first boron sensing medium with the first sample of the aqueous solution after removal of boron, wherein the first boron sensing medium comprises at least two hydroxyl groups and at least one pyridinic nitrogen, or pyrrolic nitrogen, or quaternary nitrogen;~~
 - ~~obtaining a first conductivity measurement by measuring conductivity of the first sample of the aqueous solution after removal of boron and contact with the first boron sensing medium;~~
 - ~~contacting a second boron sensing medium with a second sample of the aqueous solution to form a complex with boron in the second sample, wherein the second boron sensing medium comprises at least two hydroxyl groups and at least one pyridinic nitrogen, or pyrrolic nitrogen, or quaternary nitrogen;~~
 - ~~obtaining a second conductivity measurement by measuring conductivity of the second sample of the aqueous solution after formation of the complex; and~~
 - ~~correlating the difference in the first and second conductivity measurements to the amount of boron present in the aqueous solution.~~

38. — The method according to claim 37, wherein each of the first and second boron sensing media comprises at least two hydroxyl groups and at least one pyrrolic nitrogen.
39. — The method according to claim 37, wherein each of the first and second boron sensing media comprises at least four hydroxyl groups and at least two pyrrolic nitrogen.
40. — The method according to claim 37, wherein each of the first and second boron sensing media comprises pyridoxine or a derivative thereof.
41. — The method according to any one of claim 37 to 40, wherein the amount of boron detected and quantified is less than 1 ppb.
42. — The method according to claim 41, wherein amount of boron detected and quantified is less than 1 ppt.
43. — Use of a boron sensing medium in detecting and quantifying the amount of boron present in an aqueous solution by a conductometric measurement technique, wherein the boron exists in a form of boric acid (H_3BO_3) or borate ions ($\text{B}(\text{OH})_4^-$, $\text{B}_4\text{O}_7^{2-}$, H_3BO_2^-) in the aqueous solution, wherein the boron sensing medium comprises at least two hydroxyl groups and at least one pyridinic nitrogen, or pyrrolic nitrogen, or quaternary nitrogen.
44. — The use according to claim 43, wherein the boron sensing medium comprises at least two hydroxyl groups and at least one pyrrolic nitrogen.
45. — The use according to claim 43, wherein the boron sensing medium comprises at least four hydroxyl groups and at least two pyrrolic nitrogen.
46. — The use according to claim 43, wherein the boron sensing medium comprises pyridoxine or a derivative thereof.