CLAIMS

1. A method of recovering a target metal from a pregnant aqueous solution containing the target metal, the method comprising:

(a) a biosorption step comprising contacting a microorganism with the pregnant aqueous solution such that at least a portion of the target metal biosorb to the microorganism, in which the microorganism becomes metal laden and the pregnant aqueous solution becomes a barren solution;

(b) a separating step comprising substantially separating the metal laden microorganism from the barren solution; and

(c) a recovery step comprising recovery of the target metal from the metal laden microorganism;

in which the concentration factor of the target metal from the pregnant aqueous solution to the microorganism is greater than 5, and in which substantially all of the target metal is recovered from the solution.

2. A method according to Claim 1, in which the biosorption step (a) comprises contacting a microorganism with the pregnant aqueous solution such that substantially all of the dissolved target metal biosorbs to the microorganism.

3. A method according to Claim 1 or 2, in which the pregnant aqueous solution contains more than 10ppm of the target metal.

4. A method according to Claim 1, 2 or 3, in which the barren aqueous solution contains less than 1ppm of the target metal.

5. A method according to Claim 4, in which the barren aqueous solution contains substantially no target metal.

6. A method according to Claim 5, in which the barren aqueous solution contains no detectable target metal.

7. A method according to any preceding claim, in which the concentration factor of the target metal from the pregnant aqueous solution to the microorganism is greater than 10.

8. A method according to any preceding claim, in which in the biosorption step the microorganism is in contact with the pregnant aqueous solution for between 0.5 and 48 hours.

9. A method according to any preceding claim, in which the target metal is gold.

10. A method according to any preceding claim, in which the microorganism is a Gram-negative or Gram-positive bacteria.

11. A method according to any preceding claim, in which the microorganism is selected from an environment where the target metal is found in a physiologically relevant amount.

12. A method according to any preceding claim, in which the separation step includes at least one of:

gravity separation of the metal laden microorganism from the barren aqueous solution and removal of the barren solution,

centrifugation and removal of the barren solution;

filtration of the metal laden microorganism from the barren solution.

13. A method according to Claim 12, in which at least 60% of the barren aqueous solution is removed.

14. A method according to any preceding claim, in which the recovery step includes contacting the metal laden microorganism with a condition which triggers the microorganism to substantially desorb the target metal.

15. A method according to Claim 14, in which the condition is a solution containing a compound that triggers desorption of the target metal, in which the compound is selected from any one or more of cysteine, or thiosulphate, or thiourea.

16. A method according to Claim 14, in which the condition that triggers desorption of the target metal is a pH less than 5.

17. A method according to any of Claims 1 to 13, in which the recovery step includes burning or chemical dissolution of the metal laden microorganism to desorb the target metal.

18. A method according to any preceding claim, in which the pregnant solution includes at least one further metal, the microorganism preferentially biosorbs the target metal over the further metal in the biosorption step, and the further metal(s) remains in the barren solution in the separating step.

19. A method according to Claim 18, in which the microorganism preferentially biosorbs the target metal over the further metal in the biosorption step such that the mass ratio of target metal to further metal in the microorganism increases by a factor of at least 2 when compared to the mass ratio in the pregnant solution.

20. A method according to Claim 19, in which the further metal is selected from one or more of copper and nickel.

21. A method of recovering a target metal, the method comprising:

(a) a dissolution step comprising dissolving the target metal from a solid feedstock material with a lixiviant to form a pregnant aqueous solution containing target metal ions;

(b) a biosorption step comprising contacting a microorganism with the pregnant aqueous solution such that substantially all of the target metal ions biosorb to the microorganism in which the microorganism becomes metal laden, and the pregnant aqueous solution becomes a barren solution;

(c) a separating step comprising substantially separating the metal laden microorganism from the barren solution; and

(d) a recovery step comprising recovery of the target metal from the metal laden microorganism;

in which the concentration factor of the target metal from the pregnant aqueous solution to the microorganism is greater than 5.

22. A method according to Claim 21, in which the solid feedstock material comprises a solid material comprising less than 5% of target metal.

23. A method according to Claim 21 or 22, in which the solid feedstock material is any one or more of an ore, a tailing or e-waste.

24. A method according to Claim 21, 22 or 23, in which the target metal is gold, the solid feedstock material is e-waste, or gold bearing ore, or gold bearing sand, or gold bearing clay.

25. A method according to any of Claims 21 to 24, in which the lixiviant solution is a thiourea-based solution, or a thiosulphate-based solution, or a thiocyanate-based solution, or a cyanide-based solution, or a halogen-based solution, or an aqua regia-based solution.

CLAIMS

1. A method of recovering a target metal from a pregnant aqueous solution containing dissolved target metal, the method comprising:

(a) a dissolution step comprising dissolving the target metal from a solid feedstock material with a lixiviant to form a pregnant aqueous solution containing the target metal ions;

(b) a biosorption step comprising contacting a microorganism with the pregnant aqueous solution such that at least a portion of the dissolved target metal biosorb to the microorganism, in which the microorganism becomes metal laden and the pregnant aqueous solution becomes a barren solution;

(c) a separating step comprising substantially separating the metal laden microorganism from the barren solution; and

(d) a recovery step comprising recovery of the target metal from the metal laden microorganism;

in which the concentration factor of the target metal from the pregnant aqueous solution to the microorganism is greater than 5;

in which the target metal is gold and the lixiviant solution is a halogen-based solution.

2. A method according to Claim 1, in which

(a) the pregnant aqueous solution contains more than 10ppm of the target metal; or

(b) the barren aqueous solution contains less than 1ppm of the target metal; or

(c) the concentration factor of the target metal from the pregnant aqueous solution to the microorganism is greater than 10;

(d) any combination of two or more of (a) to (c) above.

3. A method according to any preceding claim, in which in the biosorption step the microorganism is in contact with the pregnant aqueous solution for between 0.5 and 48 hours.

4. A method according to any preceding claim, in which the microorganism:

(a) is a Gram-negative or Gram-positive bacteria; and/or

(b) is selected from an environment where the target metal is found in a physiologically relevant amount.

5. A method according to any preceding claim, in which the separation step includes at least one of:

(a) gravity separation of the metal laden microorganism from the barren aqueous solution and removal of the barren solution,

(b) centrifugation and removal of the barren solution;

(c) filtration of the metal laden microorganism from the barren solution;

(d) any one of (a) to (c) above in which at least 60% of the barren aqueous solution is removed.

6. A method according to any preceding claim, in which the recovery step includes:

(a) contacting the metal laden microorganism with a condition which triggers the microorganism to substantially desorb the target metal; or

(b) burning or chemical dissolution of the metal laden microorganism to desorb the target metal.

7. A method according to Claim 6, in which the condition that triggers desorption of the target metal is:

(a) a solution containing a compound that triggers desorption of the target metal, in which the compound is selected from any one or more of cysteine, or thiosulphate, or thiourea; or

(b) a pH less than 5.

8. A method according to any preceding claim, in which the pregnant solution includes at least one further metal, the microorganism preferentially biosorbs the target metal over the further metal in the biosorption step, and the further metal(s) remains in the barren solution in the separating step.

9. A method according to any preceding claim, in which the pregnant solution includes at least one further metal, and the microorganism preferentially biosorbs the target metal over the further metal in the biosorption step such that the mass ratio of target metal to further

metal in the microorganism increases by a factor of at least 2 when compared to the mass ratio in the pregnant solution.

10. A method according to Claim 8 or 9, in which the further metal is selected from one or more of copper and nickel.

11. A method according to Claim 1, in which the solid feedstock material

(a) comprises a solid material comprising less than 5% of target metal; and/or

(b) is any one or more of an ore, a tailing or e-waste.

12. A method according to Claim 1 or 11, in which:

(a) when present, the solid feedstock material is e-waste, or

(b) when present, the solid feedstock material is gold bearing ore, or

(c) when present, the solid feedstock material is gold bearing sand, or

(d) when present, the solid feedstock material is gold bearing clay, or

(e) any combination of two or more of (a) to (d) above.