CLAIMS

1. A method of treating a solid metallic or metal-bearing material, comprising one or more metals in metallic or compound form, to recover one or more of the metals from the metallic or metal-bearing material in metallic or compound form, the method including

in an oxidative or reductive digestion step, producing an aqueous ferrous chloride ($FeCl_2$) solution by contacting the metallic or metal-bearing material with a digestion reagent selected from

gaseous hydrochloric acid (HCl), when the metallic or metal-bearing material comprises iron,

HCl in aqueous solution, when the metallic or metal-bearing material comprises iron, and

an aqueous solution of ferric chloride ($FeCl_3$) produced by reacting iron (III) oxide (Fe_2O_3) with HCl, in aqueous medium,

and reducing any $FeCl_3$ in solution, produced from the contacting of the metallic or metal-bearing material with the digestion reagent, to $FeCl_2$ in solution;

in a crystallisation step, crystallising a solid ferrous chloride hydrate ($FeCl_2 \cdot xH_2O$, wherein $x > 1$) from the $FeCl_2$ solution;

in a dehydration step, subjecting the $FeCl_2 \cdot xH_2O$ to temperature treatment in a non-oxidising environment at a temperature from 70°C to 150°C, to produce dehydrated solid ferrous chloride hydrate ($FeCl_2 \cdot yH_2O$, wherein $x>y>0$); and

in a thermal decomposition step, subjecting the $FeCl_2 \cdot yH_2O$ to temperature treatment in an oxidising environment at a temperature above 200°C but not higher than 600°C and thus decomposing the $FeCl_2 \cdot yH_2O$ to produce solid ferric oxide (Fe_2O_3) and anhydrous gaseous HCl.

2. The method according to claim 1, wherein the digestion reagent is

gaseous HCl, produced in the thermal decomposition step;

an aqueous solution of HCl, produced by scrubbing gaseous HCl produced in the thermal decomposition step with water;

an aqueous solution of HCl, produced by scrubbing gaseous HCl produced in the thermal decomposition step with an aqueous suspension or slurry of the solid metallic or metal-bearing material;

an aqueous solution of $FeCl_3$, produced by contacting solid Fe_2O_3 produced in the thermal decomposition step with an aqueous solution of HCl produced by scrubbing gaseous HCl produced in the thermal decomposition step with water; or

an aqueous solution of $FeCl_3$, produced by scrubbing gaseous HCl produced in the thermal decomposition step with an aqueous suspension of solid Fe_2O_3 produced in the thermal decomposition step.

3. The method according to claim 1, wherein crystallising the $FeCl_2 \cdot xH_2O$ from the $FeCl_2$ solution is effected by means of displacement crystallisation, by contacting, and saturating, the $FeCl_2$ solution with gaseous HCl produced in the thermal decomposition step, thus producing solid $FeCl_2.xH_2O$ in an aqueous solution of HCl.

4. The method according to claim 3, which includes

separating solid $FeCl_2.xH_2O$, and any other solid metal chloride hydrates that crystallised along with the $FeCl_2.H_2O$ in the crystallisation step, from the aqueous solution of HCl thus produced; and

using the aqueous solution of HCl as, or in producing, the digestion reagent in the digestion step.

5. The method according to any of claims 1 to 4, wherein

the metals of the metallic or metal bearing material include iron (Fe) and one or more other metals (M) selected from chrome (Cr), copper (Cu), vanadium (V), nickel (Ni), cobalt (Co), zinc (Zn), titanium (Ti), manganese (Mn), in metallic or compound forms selected from metal oxide form and metal sulphide form;

the $FeCl_2$ solution thus contains, in addition to $FeCl_2$, one or more additional metal chlorides ($M^{2+}Cl_2$, wherein M is selected form chrome (Cr), copper (Cu), vanadium (V), nickel (Ni), cobalt (Co), zinc (Zn), titanium (Ti), and manganese (Mn)), in solution; and

the crystallisation step thus forms, in addition to $FeCl_2 \cdot xH_2O$, one or more other solid metal chloride hydrates ($M^{2+}Cl_2 \cdot zH_2O$, wherein M is selected from one or more of chrome (Cr), copper (Cu), vanadium (V), nickel (Ni), cobalt (Co), zinc (Zn), titanium (Ti), and manganese (Mn), and $z>0$).

6. The method according to any of claims 1 to 5, which includes,

in a first separation step, performed after the digestion step, separating solids from the $FeCl_2$ solution by means of solid-liquid separation, thus recovering the $FeCl_2$ solution substantially free of solids; and

in a second separation step, performed after the crystallisation step and before the dehydration and decomposition steps, recovering solid $FeCl_2 \cdot xH_2O$ and any other solid metal chloride hydrates ($M^{2+}Cl_2 \cdot zH_2O$, wherein M is selected from one or more of chrome (Cr),

copper (Cu), vanadium (V), nickel (Ni), cobalt (Co), zinc (Zn), titanium (Ti), and manganese (Mn), and z>0) that crystallised with the $FeCl_2.xH_2O$ in the crystallisation step.

7. The method according to claim 6, wherein, in the dehydration step recovered solid $M^{2+}Cl_2 \cdot zH_2O$ also subjected to dehydration, along with recovered $FeCl_2 \cdot xH_2O$, thereby producing, in addition to $FeCl_2 \cdot yH_2O$, dehydrated other solid metal chloride hydrates or anhydrous metal chlorides ($M^{2+}Cl_2 \cdot aH_2O$, wherein and $z>a\geq 0$).

8. The method according to claim 7, wherein

solid $M^{2+}Cl_2 \cdot aH_2O$ recovered from the dehydration step is subjected to temperature treatment in the thermal decomposition step along with the $FeCl_2 \cdot yH_2O$; and

thermal decomposition of $FeCl_2 \cdot yH_2O$ occurs to the exclusion of solid $M^{2+}Cl_2 \cdot aH_2O$, of which hydrates thereof are fully dehydrated in the thermal decomposition step, thus producing a mixture of solid Fe_2O_3 and solid other anhydrous metal chlorides ($M^{2+}Cl_2$).

9. The method according to any of claims 1 to 8, wherein x = 4 and y = 1.