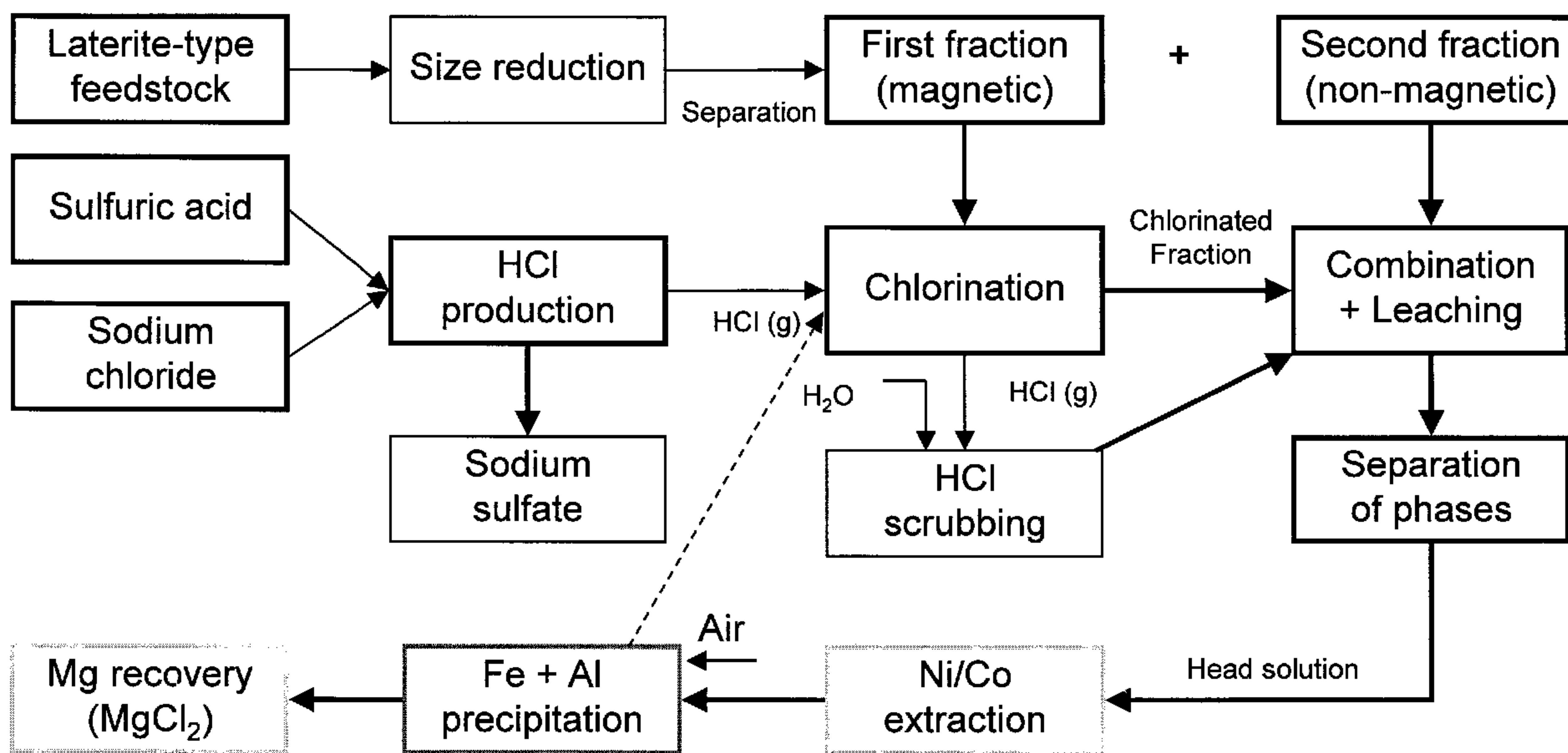




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(54) Titre : PROCESSUS DE RECUPERATION D'ESPECE METALLIQUE DE VALEUR A PARTIR DE MATIERE  
PREMIERE DU TYPE LATERITE  
(54) Title: PROCESS FOR RECOVERING VALUE METAL SPECIES FROM LATERITE-TYPE FEEDSTOCK



(57) **Abrégé/Abstract:**

An essentially open-circuit process for recovering value metal species from a laterite-type feedstock, the process comprising the sequential or unsequential steps of separating the laterite-type feedstock into a first and a second fraction; reacting an acid with a chloride salt in a first compartment, thereby generating gaseous HCl; chlorinating the first fraction with the gaseous HCl in a second compartment, thereby producing a chlorinated fraction, wherein excess HCl is recovered and dissolved in water, thereby producing a concentrated HCl solution; combining the chlorinated fraction and the second fraction into a mixture; leaching the mixture with the concentrated HCl solution in a third compartment, thereby producing a reaction mass; submitting the reaction mass to a separation of phases, thereby separating an insoluble residue from a head solution; and selectively recovering value metal species from the head solution.



**ABSTRACT OF THE DISCLOSURE**

An essentially open-circuit process for recovering value metal species from a laterite-type feedstock, the process comprising the sequential or unsequential steps of separating the laterite-type feedstock into a first and a second fraction; reacting an acid with a chloride salt in a first compartment, thereby generating gaseous HCl; chlorinating the first fraction with the gaseous HCl in a second compartment, thereby producing a chlorinated fraction, wherein excess HCl is recovered and dissolved in water, thereby producing a concentrated HCl solution; combining the chlorinated fraction and the second fraction into a mixture; leaching the mixture with the concentrated HCl solution in a third compartment, thereby producing a reaction mass; submitting the reaction mass to a separation of phases, thereby separating an insoluble residue from a head solution; and selectively recovering value metal species from the head solution.

**TITLE OF THE INVENTION**

**[0001]** Process for recovering value metal species from laterite-type feedstock.

**FIELD OF THE INVENTION**

**[0002]** The present invention relates to a process for recovering value metal species from laterite-type feedstock. More specifically, the present invention relates to a process for recovering metal species such as nickel, cobalt, iron, aluminum and/or magnesium from laterite-type feedstock.

**BACKGROUND OF THE INVENTION**

**[0003]** Laterite minerals consist of residual weathering products of rocks such as basalts, granites and shales. These metamorphic materials are found on all continents in tropical or semi-tropical zones. They can have variable compositions where iron, aluminum, magnesium and/or silica predominate. In several instances, significant amounts of nickel and cobalt are associated with the dominant constituents.

**[0004]** Serpentine minerals can also be found associated with laterites ores. Serpentine is a magnesium-rich silicate mineral that is found as a major constituent in many metamorphic and weathered igneous rocks. Some serpentinic minerals contain significant amounts of nickel and cobalt.

**[0005]** A large number of processes have been reported in order to gain access to the nickel/cobalt values, in laterite ores or other materials. These processes can be grouped in four broad categories, namely:

- a) Pressure leaching or atmospheric pressure leaching;

- b) Acidic or basic leaching;
- c) Reductive or oxidative leaching; and
- d) Open or closed circuit leaching.

**[0006]** In many instances, two or more of these categories are combined, such as in the well-known and commercially used processes of Pressure Acid Leaching (PAL) or Ammonia Leaching (the Caron Process).

**[0007]** In PCT application No. WO 02/08477 published January 31, 2002, Lalancette discloses a closed-circuit method for recovering nickel and cobalt from laterite ores, which essentially comprises the steps of grinding the ore, treating the ore with gaseous hydrochloric acid (gaseous HCl), wherein the remainder of gaseous HCl is scrubbed with water into a concentrated HCl solution, curing the ores in the concentrated HCl solution, followed by filtration of the resulting lixivate and selective recovery of nickel and cobalt with known techniques. Gaseous HCl is thereafter recycled by roasting or pyrohydrolysis at a minimum of 450°C and returned to the treating stage.

**[0008]** However, high temperature roasting, which allows recycling of the leaching agent or part of it, often fails to provide a significant commercial advantage regarding capital or operation costs and remains more difficult to implement.

**[0009]** In PCT application No. WO 2005/093107, published October 6, 2005, Moyes et al. disclose a process for recovering a target metal from an oxidized metalliferous material comprising the steps of: leaching the oxidized metalliferous material with an acidic aqueous halide solution to leach the target metal into solution, the leaching solution being generated by adding sulfuric acid to a solution comprising a metal halide; passing the solution from the leaching stage to a target metal recovery stage in which the target metal is recovered from the

solution whilst the metal halide is retained in solution; and returning the solution with the metal halide therein from the target metal recovery stage to the leaching stage. The process preferably comprises two leaching stages, wherein the solid residue from the first leaching stage is directed to the second leaching stage, and the liquid residue of the second leaching stage is at least partially redirected to the first leaching stage. The process also possibly includes a separate hydrohalous acid generation stage in which sulfuric acid is added to a solution comprising the metal halide, thereby forming an acidic leaching solution that is then fed to the second leaching stage and mixed with the first leached solids.

**[0010]** However, this two-step leaching process seems unduly complicated since it requires recycling part of the respective residues of each leaching step into the other. It also seems to leave the residual solid material loaded with halide solution that has to be removed before discarding, which adds a substantial operational complication.

**[0011]** Thus remains a need for a simple and economical process for the recovery of value metal species from laterite-type feedstock.

### **SUMMARY OF THE INVENTION**

**[0012]** The present invention generally relates to an essentially open-circuit process for recovering value metal species from a laterite-type feedstock.

**[0013]** More specifically, in accordance with the present invention, there is provided an essentially open-circuit process for recovering value metal species from a laterite-type feedstock, the process comprising the sequential or unsequential steps of:

- a) separating the laterite-type feedstock into a first and a second fraction;
- b) reacting an acid with a chloride salt in a first compartment, thereby generating gaseous HCl;
- c) chlorinating the first fraction with the gaseous HCl in a second compartment, thereby producing a chlorinated fraction, wherein excess HCl is recovered and

- dissolved in water, thereby producing a concentrated HCl solution;
- d) combining the chlorinated fraction and the second fraction into a mixture;
  - e) leaching the mixture with the concentrated HCl solution in a third compartment, thereby producing a reaction mass;
  - f) submitting the reaction mass to a separation of phases, thereby separating an insoluble residue from a head solution; and
  - g) selectively recovering value metal species from the head solution.

**[0014]** Other objects, advantages and features of the present invention will become more apparent upon reading of the following non-restrictive description of specific embodiments thereof, given by way of example only with reference to the accompanying drawings.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

**[0015]** In the appended drawings:

**[0016]** Figure 1 is a block diagram illustrating the broad aspects of the process of the present invention.

**[0017]** Figure 2 is a block diagram illustrating the various steps of an embodiment of the process of the present invention.

#### **DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS**

**[0018]** In general terms, the present invention relates to an essentially open-circuit process for recovering value metal species from a laterite-type feedstock.

**[0019]** As used herein, the expression "laterite-type feedstock" refers to nickel-containing sedimentary oxide materials that are relatively rich in iron oxide, magnesium oxide and/or aluminum oxide, and/or nickel-containing magnesium-rich

silicates, which possibly further contain trace amounts of cobalt and/or chromium. Non-limiting examples of such laterite-type feedstock include laterites, laterite ores, lateritic materials, serpentine, serpentine ores, serpentinitic materials and talc.

**[0020]** As used herein, the expression "value metal species" refers to any valuable metal species that can be found in the laterite-type feedstock, non-limiting examples of which include nickel, cobalt, iron, aluminum, magnesium and chromium.

**[0021]** As used herein, the expression "essentially open-circuit process" means that the process is mainly unidirectional, in a forward direction, that the hydrochloric acid, when combined to give an essentially stable chloride, is not recycled after the leaching step and that a by-product is recovered and used for itself outside the process, without being recycled to a step that precedes its formation in the overall process. It is to be understood that an "essentially open-circuit" process as used herein does not preclude a product or reagent used in the process to be redirected to another step of the overall process.

**[0022]** As used herein when referring to a metal with which HCl may be combined during the process of the present invention, an "essentially stable chloride" refers to a metal chloride that would not be hydrolyzed under oxidant conditions at a temperature less than 400°C, a non-limiting example of which is magnesium chloride. As used herein, the contrary of this expression would be an "essentially unstable chloride", non-limiting examples of which are iron or aluminum chlorides.

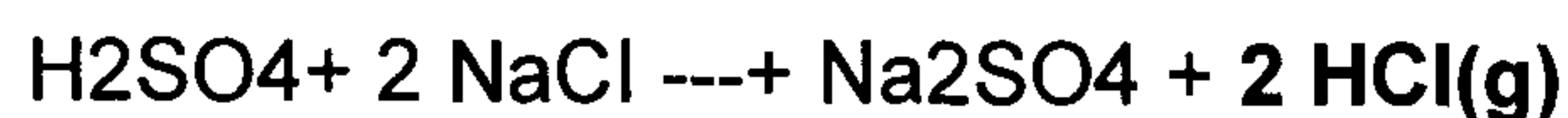
**[0023]** Referring now to Figure 1, gaseous HCl is generated by reacting an acid with a chloride salt in a first compartment, while the laterite-type feedstock is separated into a first and a second fraction. These steps are in no particular order and can be performed simultaneously and independently.

**[0024]** The hydrochloric acid generation can involve different couples of acid/chloride salts, non-limiting examples of which are sulfuric acid/sodium chloride, sulfuric acid/calcium chloride, sulfuric acid/potassium chloride, nitric acid/sodium chloride, nitric acid/potassium chloride or phosphoric acid/sodium chloride (although this

last example is not preferred because of the rather low reactivity of phosphoric acid.

**[0025]** The first fraction of feedstock is then chlorinated with gaseous HCl (which constitutes a first, dry digestion) in a second compartment, and the resulting chlorinated fraction is combined with the second fraction of feedstock. Unreacted gaseous HCl is dissolved in water, thereby forming a concentrated HCl solution, which is used for leaching the combined fractions (which constitutes a second, wet digestion), in a third compartment. In operation, both the combination of the "chlorinated" and "second" fractions and leaching may occur simultaneously. The reaction mass resulting from the leaching is then submitted to a separation of phases, which produces an insoluble residue (solid) and a head solution (liquid). This head solution is thereafter subjected to further conventional steps allowing selectively recovering value metal species, including in particular nickel, cobalt, iron, aluminum and magnesium.

**[0026]** Referring now to Figure 2, which illustrates a more particular embodiment of the present invention, gaseous hydrochloric acid is generated by reaction of sulfuric acid with sodium chloride, which are both very cheap reagents, according to the following equation:



**[0027]** Hydrochloric acid is advantageous because of its fast dissolving capability, as compared to sulfuric or phosphoric acid for example. Since hydrochloric acid is about five times more expensive than sulfuric acid on an acidic-proton basis, *in situ* generation of hydrochloric acid from sulfuric acid provides a substantial economy. In addition, such reaction further generates a sellable product, namely sodium sulfate (in form of a salt cake), used in large amounts in pulp and paper production, glass making and other industries. This by-product may therefore substantially amortize the cost of the reagents required to produce the hydrochloric acid.

**[0028]** The amount of gaseous HCl needed is determined experimentally and depends on the feedstock composition. For example, the more iron or magnesium is present in the feedstock, the higher amount of HCl will generally be needed.

**[0029]** The acid-generation reaction from sulfuric acid and sodium chloride is performed at a temperature between 300 and 400°C and therefore requires an input of energy. However, from that point, the highly reactive hot gaseous HCl, by the reaction with the first fraction, liberates a substantial amount of energy so that the following chlorination and leaching steps can be operated without further energy input, which is another significantly cost-effective aspect of the process of the present invention at an industrial scale.

**[0030]** According to a particular embodiment of the present invention (as seen in Figure 2), the laterite-type feedstock is separated into a magnetic and a non-magnetic fractions. In such a case, the "first fraction" used for chlorination is the magnetic fraction, which tends to be more acidic (since it is richer in iron and silica) and therefore less reactive in the presence of another acid. The process of the present invention thus takes advantage of the high reactivity of the hot gaseous HCl produced to operate a reaction that would otherwise have been difficult. The leaching is then done on the combination of the magnetic, chlorinated fraction and the nonmagnetic fraction (which tends to be more basic since it is richer in alumina and magnesia). These chlorination and leaching reactions are advantageously performed at temperatures ranging from about 90 to about 120°C, preferably about 100°C. The dry chlorination takes approximately 15 to 30 minutes and the wet leaching step preferably for a duration of from 4 to 9 hours.

**[0031]** In another embodiment of the present invention, which occurs mainly in a case where a magnetic separation would not give substantial magnetic and non-magnetic fractions, the laterite-type feedstock is simply separated into two fractions of approximately equal weight before treatment by HCl.

**[0032]** The chlorination and leaching steps are usually performed at atmospheric pressure, thereby limiting operation costs. These reactions are usually made in vats or stirred reactors.

**[0033]** Following the leaching step, the reaction mass, comprised of solid particles and a liquid lixiviate, is filtered or centrifuged (separation of phases in Figure 2)

and the insoluble residue discarded, optionally after rinsing. The nickel/cobalt chlorides are then recovered from the resulting head solution (to which the rinsing solution is optionally added) by conventional techniques, such as, contacting with selective ion exchange resins, solvent extraction, electrowinning or sulfide precipitation.

**[0034]** The first soluble residue after Ni/Co removal is then usually deprived of iron and aluminum by simple pH adjustment in the range of 3-3.5 after aeration. The resulting second soluble residue is then adjusted to a pH ranging between 6 and 7, and reduced in volume so as to separate magnesium chloride, which may be crystallized as a solid and/or commercialized as such.

**[0035]** However, in the case of a relatively high-iron (for example, with an iron content of more than 8% of the feedstock dried at 100° C) and low-magnesium feedstock, the first soluble residue, still rich in iron (in the form of an essentially unstable chloride), can optionally be hydrolyzed and oxidized in the presence of air at a temperature ranging between about 200 and 400°C, preferably between about 200 and 350°C, to liberate a substantial amount of gaseous HCl, which can then be used as a chlorination agent, thereby partly replacing the NaCl/H<sub>2</sub>SO<sub>4</sub> mixture. It is to be understood that such additional step does not necessitate an energy input higher than that required for HCl production by NaCl/H<sub>2</sub>SO<sub>4</sub>.

**[0036]** Such hydrolysis converts the essentially unstable iron and aluminium chlorides into insoluble oxides, without affecting the magnesium chloride in the resulting second soluble residue. A simple rinsing may be used to recover it, followed or not by crystallization.

**[0037]** As stated above, the process according to the present invention essentially operates in "open circuit", wherein the essentially stable magnesium chloride is usually recovered as a useful product rather than submitted to a high energy-consuming, high-temperature roasting so as to recycle the hydrochloric acid. Only when a relatively high-iron feedstock allows it, HCl may advantageously be recycled by a hydrolysis at a temperature between about 200 and 400°C. In either case, the process according to the present invention may generally lead to surprisingly low operational

costs.

**[0038]** An additional step of size reduction may be added to the process of the present invention. Indeed, it has been noted that submitting the laterite-type feedstock to grinding before or after the separation step accelerates the reaction and improves the yield of metal recovery. Such grinding preferably takes place before the separation step, particularly in a case of magnetic separation, which is facilitated by smaller particles.

**[0039]** The granulometry of the feedstock resulting from such grinding may range between minus 35 and minus 200 mesh, but preferably the whole feedstock would pass through a 120 mesh screen (i.e. granulometry of 100% minus 120 mesh).

**[0040]** The process of the present invention can be advantageously applied to laterite-type feedstocks comprising (as a result of an analysis on an ore dried at 100°C): 4 to 50% iron, 0.1 to 10% aluminum, <1% to 15% magnesium and 0.2 to 5% nickel.

**[0041]** When applied to laterites with a nickel content ranging from 0.24% to 3.1%, the process of the present invention allows a recovery of nickel in the range of about 95 to 99 %, while the magnesium recovery was observed in the range of about 98 percent.

**[0042]** The useful products at the end of the process are mainly in the form of chlorides of nickel, cobalt, iron and magnesium and sulfate of sodium.

**[0043]** The present invention is illustrated in further details by the following non-limiting examples.

#### **EXAMPLE 1**

**[0044]** Five different samples of laterites originating from Brazil were treated in accordance with the process of the present invention, as further explained below.

The chemical analysis of the dry (analyzed after drying at 100°C) samples was as

follows:

**Table 1: Chemical composition of samples**

Sample	Fe %	Co %	Ni %	Mn %	Cr %	Al %	Ca %	Mg %	LOI %
1	7.70	0.07	3.09	<0.05	0.34	3.25	0.55	8.61	16.5
2	26.8	0.04	0.58	0.80	2.71	0.71	0.084	0.71	7.06
3	22.6	0.04	1.08	0.40	1.10	2.86	0.39	4.83	11.5
4	16.4	0.06	1.14	0.27	1.12	2.21	0.12	3.07	7.62
5	8.52	0.04	0.50	0.11	0.89	0.34	0.097	1.19	3.19

**[0045]** Each of these samples were reduced to minus 120 mesh and submitted to magnetic separation. In the case of samples 1 and 2, there was not a very significant magnetic fraction, as can be seen from Table 2.

**Table 2: Magnetic fractionation of samples**

Sample	Magnetic fraction	Non magnetic fraction
1	1.7%	98.3%
2	7%	93%
3	46%	54%
4	60%	40%
5	48 %	52 %

**[0046]** In the case of samples 1 and 2, the material to be treated was split into two fractions of approximately equal weight, whereas with the last three, the first fraction treated with the dry gaseous HCl was the magnetic fraction.

**[0047]** Gaseous HCl was generated by reaction of sodium chloride with sulfuric acid in a silica lined reactor at 350°C, so as to produce the required amount of HCl (which is determined experimentally).

**[0048]** The dry, gaseous HCl was first contacted with the first fraction in a Vycor tube kept at 120°C, at atmospheric pressure. The non-reacted HCl was taken up with

water and the reaction completed by leaching of the combined first and second fractions in a stirred reactor at a temperature ranging from 90°C to 120°C, still at atmospheric pressure.

**[0049]** The reason why the Vycor tube and reactor have to be maintained at the desired temperatures in this case stems from the fact that the quantities of feedstock and reagents are relatively small, and that there is an important loss of energy at such laboratory scale. At an industrial scale however, the introduction of energy would essentially be required for the generation of gaseous HCl only.

**[0050]** The residual mass was then filtered and the insoluble residue discarded after rinsing. The nickel/cobalt in solution was then collected over an ion exchange resin. Iron was then precipitated along with minor components such as chromium, aluminium and manganese, and the residual solution contained the magnesium as chloride. The conditions of reaction and extraction results are reported in Table 3 below.

**Table 3: Conditions and Results of extraction on 25 g samples**

Sample	Weight HCl (g)	Leaching duration (hrs)	Temperature (°C)	extraction results		
				% Ni	% Co	% Mg
1	12.5	9	100	94	86	99
2	8.75	8	110	100	100	96
3	14.0	7	120	100	100	99
4	13.5	7	100	100	100	97
5	5.75	5	90	100	73	98

## EXAMPLE 2

**[0051]** A dry sample of overburden from the laterite deposit of Pinares in Cuba was showing the following elemental composition (analyzed after drying at 100°C):

Sample	Fe %	Co %	Ni %	Mn %	Cr %	Al %	Mg %	LOI %
laterite, Pinares	36.4%	0.03%	0.24%	0.48%	1.60%	7.52%	0.77%	13.9%

**[0052]** A 25 gram sample of this material was submitted to a magnetic separation (wet separation of a 20% solid slurry previously reduced to minus 120 mesh, with a 5000 gauss permanent magnet). The resulting dried magnetic and non-magnetic fractions represented respectively 55% and 45% of the starting sample. The chlorination and leaching were done following the procedure described in Examples 1 to 5, the amount of HCl used being 31.5 g and the duration of the whole digestion being of 6.5 hours at 95°C. The workup of the solution gave a recovery of 96% of the nickel and of 91% of the cobalt in the starting sample.

**[0053]** It is to be noted that iron generally predominates in the feedstock sample and therefore constitutes the biggest consumer of HCl during the whole digestion. An oxydative hydrolysis of the ferrous chloride was performed on the solution after removal of the nickel and cobalt, which allowed regenerating 91% of the HCl used initially for lixiviation.

### EXAMPLE 3

**[0054]** A sample of serpentinic tailings from the chrysotile mining at Bell Mine (Black Lake, Québec, Canada) was showing the following elemental composition (analyzed after drying at 100°C):

Sample	MgO %	SiO <sub>2</sub> %	Al <sub>2</sub> O <sub>3</sub> %	Fe %	Ni %	Cr %	LOI %
serpentinic tailings, Black Lake	38.25%	38.6%	1.28%	5.2%	0.23%	0.09%	12.5%

**[0055]** A 100 g sample of this ore was dried at 100°C and reduced to minus 14 mesh in a hammer mill. The resulting mass was taken up in water to give a 10% solid pulp and the suspended chrysotile fiber was decanted. The residual weight of fiber free ore was 81.1g after drying.

**[0056]** A 25 g sample of the dried fiber free ore was reduced to minus 70 mesh in a hammer mill and separated into magnetic (41%) and non-magnetic (59%) fractions.

**[0057]** The chlorination and leaching were done as described in Example 1, the amount of HCl used being 14.9 g and the duration of whole digestion 7.5 hours at 95°C.

**[0058]** The processing of the solution indicated a recovery of 85% of the nickel and 76% of the magnesium in the starting dried fiber free ore. It is to be noted that an extraction yield is always to be read in relation to the amount of the metal species to be recovered in the feedstock. Therefore a 85% recovery of nickel where nickel is present in an amount of 0.23% in the serpentinic tailing is a very good yield.

**[0060]** The scope of the claims should not be limited by the preferred embodiments set forth in the examples, but should be given the broadest interpretation consistent with the description as a whole.

**WHAT IS CLAIMED IS:**

1. An essentially open-circuit process for recovering value metal species from a laterite-type feedstock, said process comprising the sequential or unsequential steps of:

- a) separating the laterite-type feedstock into a first and a second fraction;
- b) reacting an acid with a chloride salt in a first compartment, thereby generating gaseous HCl;
- c) chlorinating said first fraction with said gaseous HCl in a second compartment, thereby producing a chlorinated fraction, wherein excess HCl is recovered and dissolved in water, thereby producing a concentrated HCl solution;
- d) combining said chlorinated fraction and said second fraction into a mixture;
- e) leaching said mixture with said concentrated HCl solution in a third compartment, thereby producing a reaction mass;
- f) submitting said reaction mass to a separation of phases, thereby separating an insoluble residue from a head solution; and
- g) selectively recovering value metal species from said head solution.

2. The process of claim 1, wherein the acid in step b) is sulfuric acid, nitric acid or phosphoric acid.

3. The process of claim 1, wherein the chloride salt in step b) is selected from the group consisting of sodium chloride, calcium chloride and potassium chloride.

4. The process of claim 2 or 3, wherein the acid is sulfuric acid and the chloride salt is sodium chloride.

5. The process of claim 4, wherein the reacting step b) is performed at a temperature ranging between about 300 and about 400°C.
6. The process of claim 4 or 5, wherein a sodium sulfate by-product is recovered after the generation of gaseous HCl.
7. The process of any one of claims 1 to 6, wherein said first and second fractions are of approximately equal weight.
8. The process of any one of claims 1 to 6, wherein said separation in step a) is a magnetic separation.
9. The process of claim 8, wherein said first fraction is magnetic and said second fraction is non-magnetic.
10. The process of any one of claims 1-9, wherein the chlorinating step is performed at a temperature ranging between 90 and 120°C.
11. The process of any one of claims 1-9, wherein the leaching step is performed at a temperature ranging between 90 and 120°C.
12. The process of any one of claims 1-11, wherein the chlorinating and leaching steps are performed at atmospheric pressure.
13. The process of any one of claims 1-12, wherein the laterite-type feedstock is submitted to a size reduction prior to the chlorinating and leaching steps.
14. The process of claim 13, wherein the size reduction takes place before the separation step a).

15. The process of claim 13 or 14, wherein the size reduction results in a granulometry of the laterite-type feedstock ranging between minus 35 and minus 200 mesh.
16. The process of claim 13, 14 or 15, wherein the size reduction results in a granulometry of the laterite-type feedstock of 100% minus 120 mesh.
17. The process of any one of claims 1-16, wherein the separation of phases is made by filtration or centrifugation.
18. The process of claim 17, wherein said head solution is submitted to a process selected from the group consisting of electrowinning, solvent extraction, selective ion exchange resin, sulfide precipitation and pH adjustment, thereby selectively recovering at least one value metal species selected from the group consisting of nickel, cobalt, iron, aluminum and magnesium in a form of chloride salt(s).
19. The process of claim 18, wherein nickel and cobalt are recovered by contacting said head solution with a selective ion exchange resin, thereby leaving a first residual solution.
20. The process of claim 19, wherein said first residual solution is aerated and adjusted to a pH ranging between 3 and 3.5, thereby causing iron and aluminum to precipitate, leaving a second residual solution.
21. The process of claim 20, wherein said second residual solution is adjusted to a pH ranging between 6 and 7 and reduced in volume, thereby allowing recovery of magnesium in a form of magnesium chloride.

22. The process of claim 19, wherein the first residual solution is hydrolyzed and oxidized, thereby liberating gaseous HCl.

23. The process of claim 22, wherein the hydrolysis and oxidation are performed in the presence of air at a temperature ranging between about 200 and about 400°C.

24. The process of claim 23, wherein the hydrolysis and oxidation are performed in the presence of air at a temperature ranging between about 200 and about 350°C.

25. The process of claim 22, 23 or 24, wherein the liberated gaseous HCl is recycled to the chlorination step.

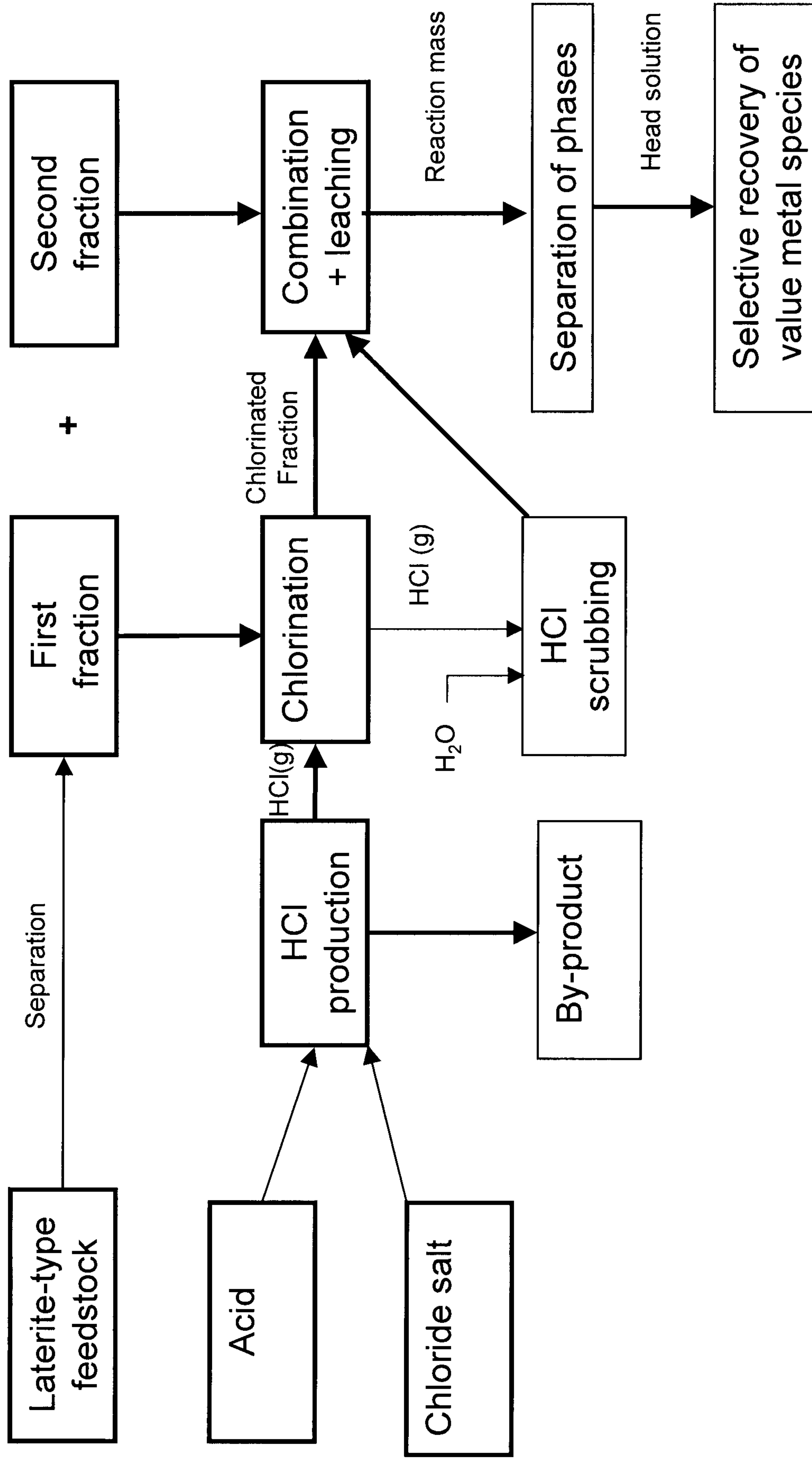


Figure 1

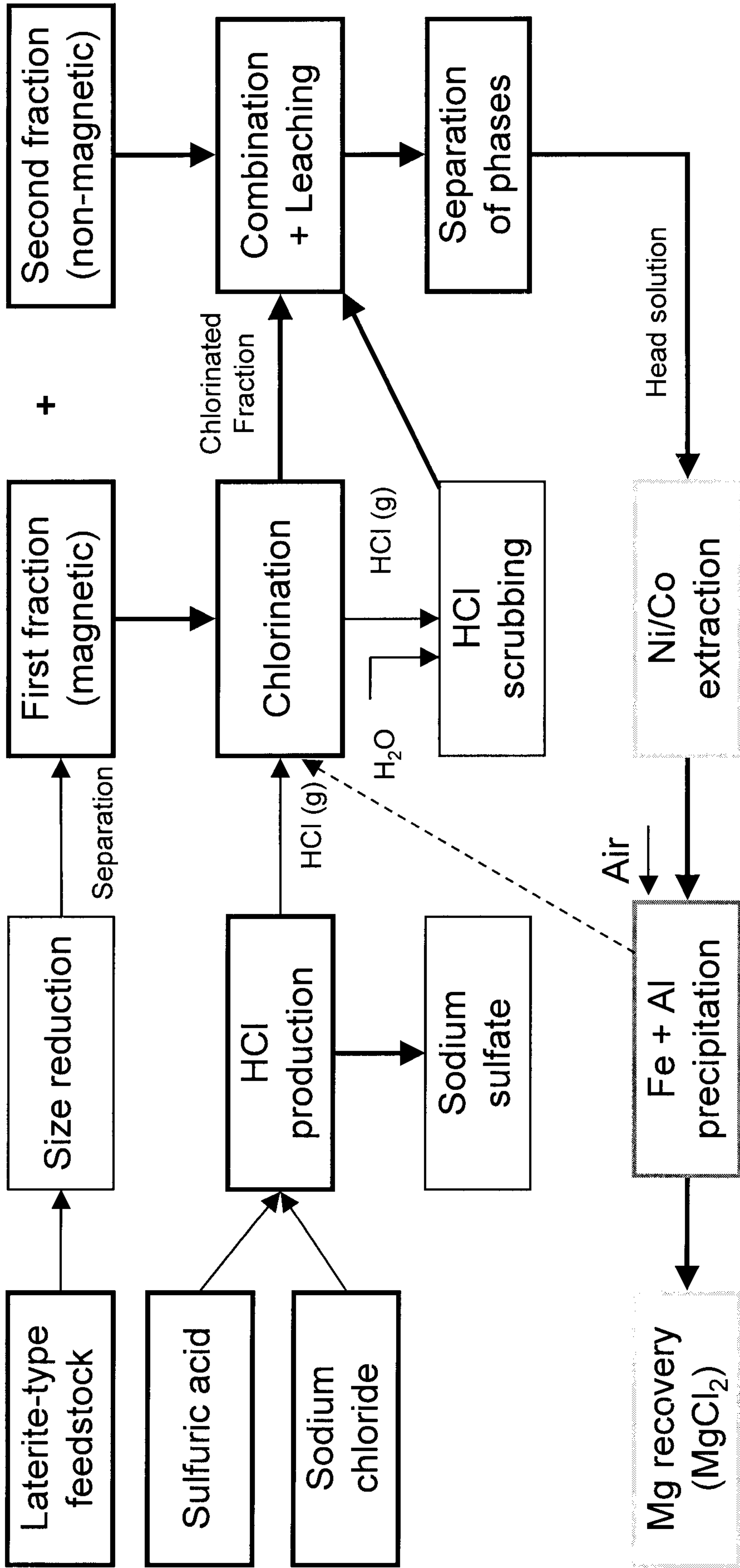


Figure 2

