Metaleach™

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MetaLeach Limited is formed to commercialise proprietary new mineral processing technologies with the potential to revolutionise the extraction processes for many base metal deposits.

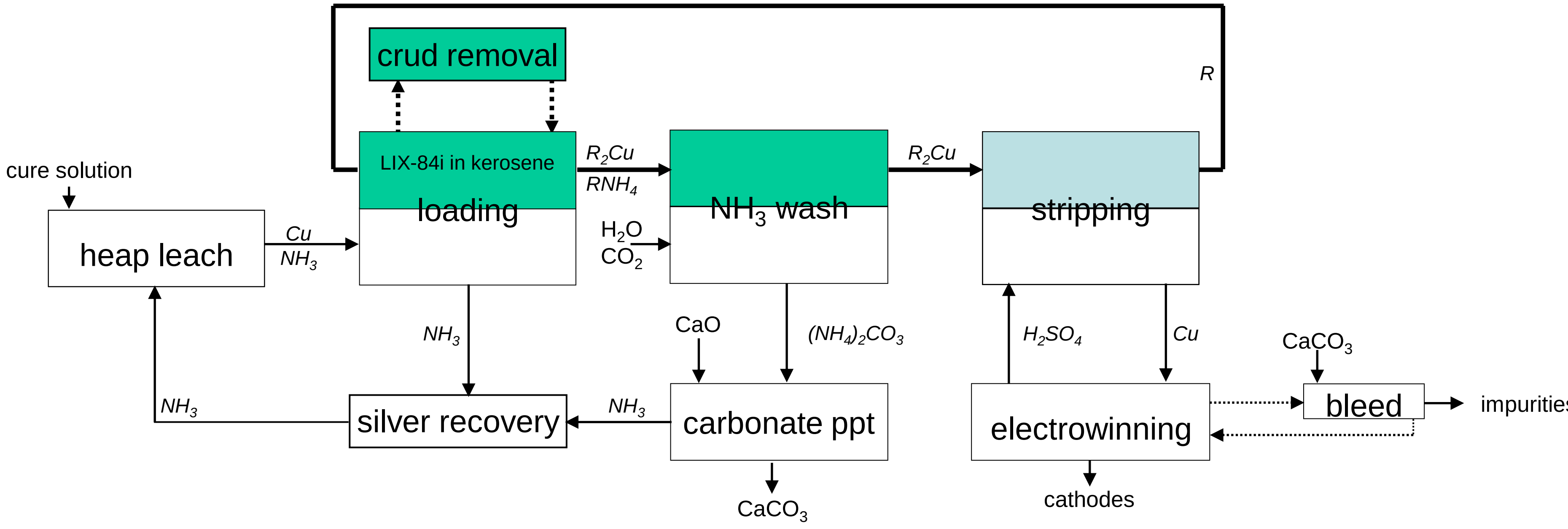
MetaLeach Ltd. owns the intellectual property to two hydrometallurgical technologies where provisional patents have been filed, namely AmmLeach® and HyperLeach™.

Ammleach®

Key features

- no special equipment required
- high selectivity for target metals
- ambient temperature and pressure
- minimal decommissioning costs
- small SX plant size for production

Leon flowsheet



Main features

cure stage

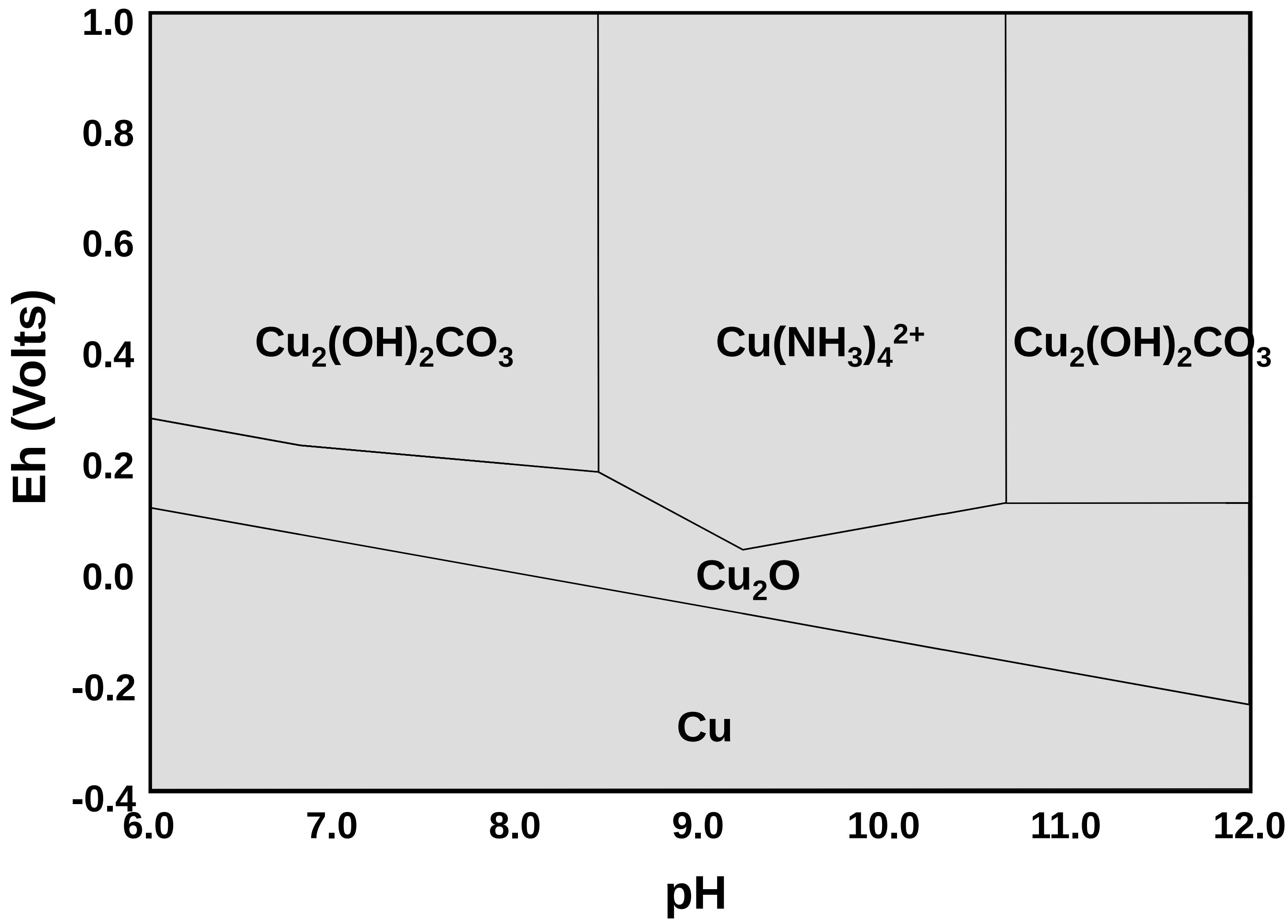
- tailored to ore
  - oxidising agent
  - reducing agent
  - complexing agent

- low volume
  - 80% of pore volume

- high concentration
  - low cost as low volume

leach stage

- complexing agent
  - ammonia
    - complexes with Cu, Zn, Ni, Co, Mo, etc
      - $Cu(NH_3)_4^{2+}$, $Zn(NH_3)_4^{2+}$ etc
    - doesn't react with iron
- buffering agent
  - ammonium carbonate
  - maintains pH at 7-11
    - minimum iron solubility



1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
Eh (Volts)
$Cu_2(OH)_2CO_3$
$Cu(NH_3)_4^{2+}$
$Cu_2(OH)_2CO_3$
Cu_2O
Cu
6.0
7.0
8.0
9.0
10.0
11.0
12.0
pH

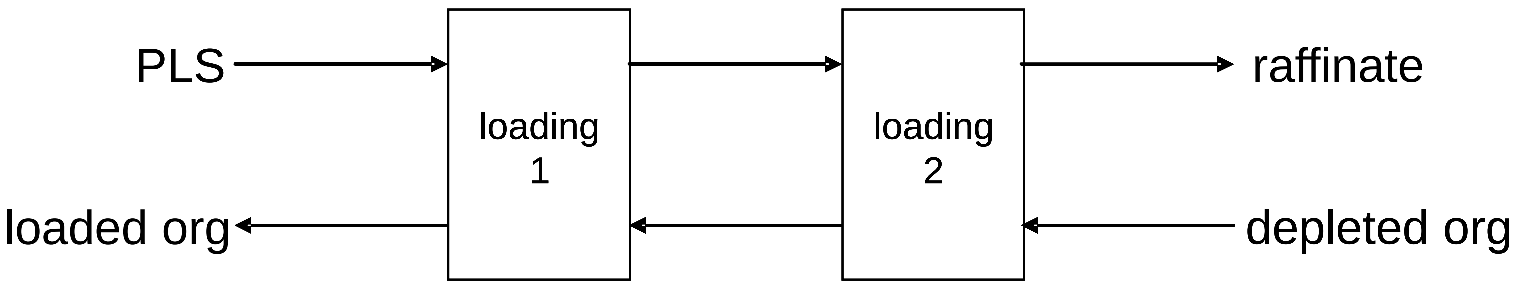
Ammleach®

- both NH_3 and $(NH_4)_2CO_3$ needed
  - $(NH_4)_2CO_3$ controls pH
  - NH_3 dissolves the copper
    - $Cu^{2+} + 4NH_3 = Cu(NH_3)_4^{2+}$
    - 1.0 kg NH_3 = 0.93 kg Cu

- high free NH_3
  - increased copper tenor in solution
  - faster kinetics
  - increased extraction of ammonia during SX
  - loss of NH_3 increases

solvent extraction, SX

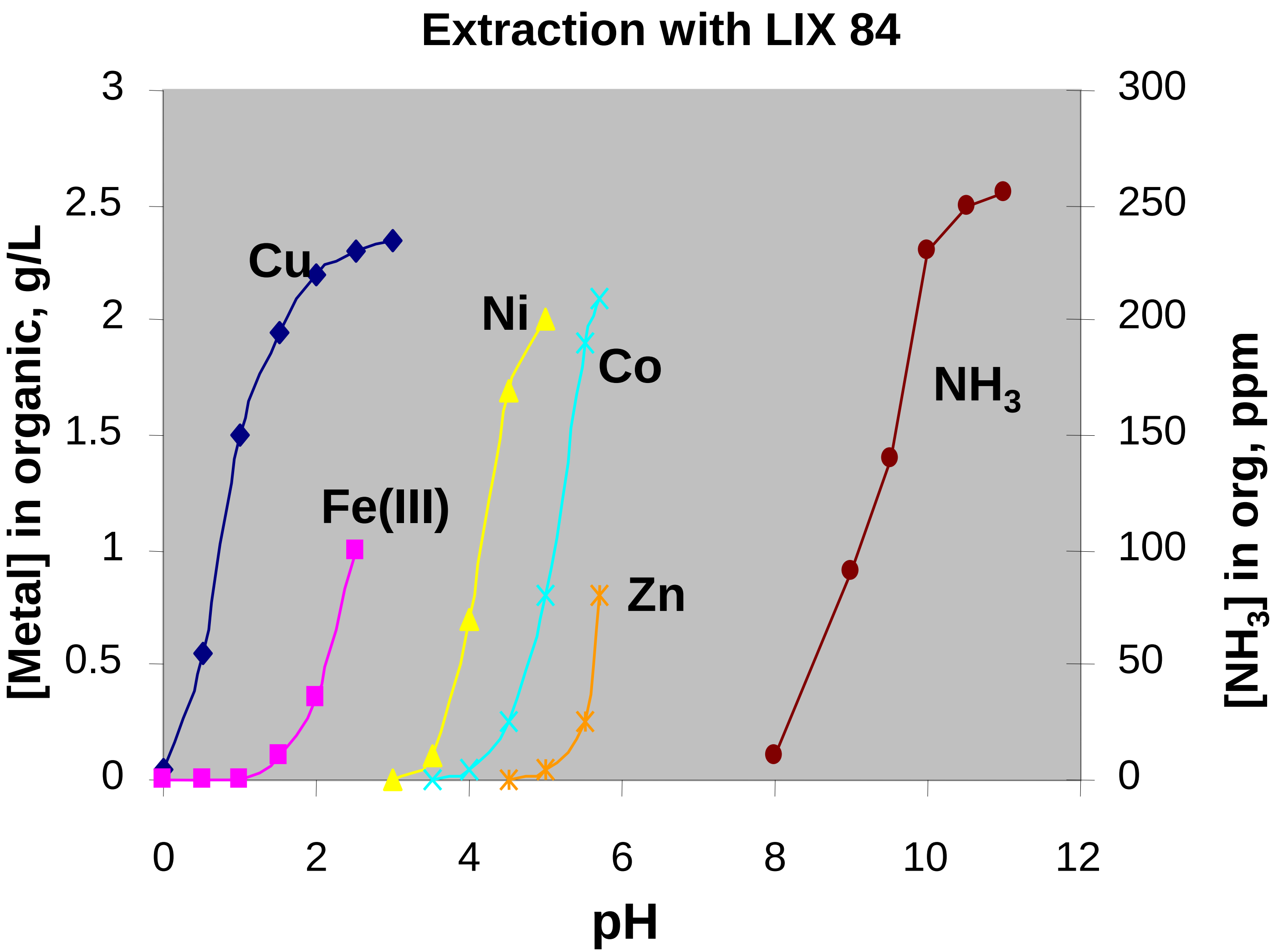
- loading



$$2RH + Cu(NH_3)_4^{2+} = R_2Cu + 2H^+ + 4NH_3$$

$$RH + NH_3 = RH.NH_3$$

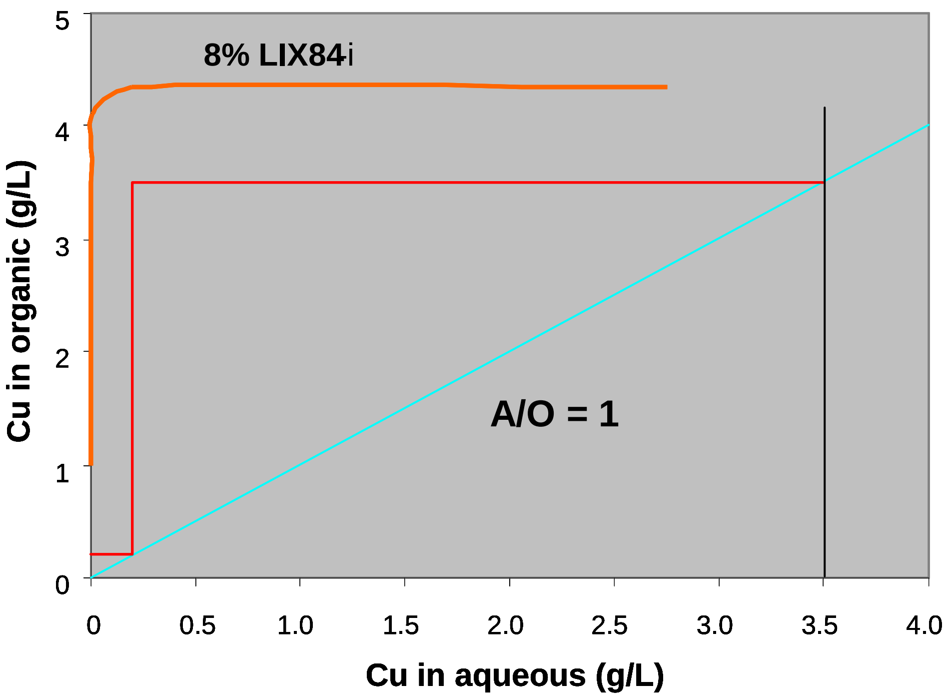
R = LIX84-IC

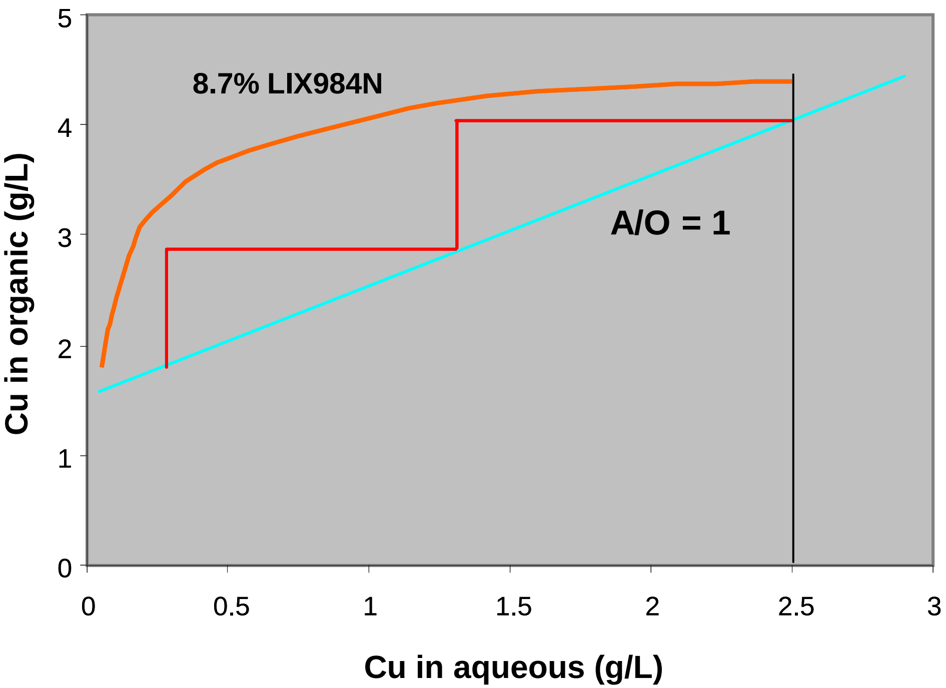


Extraction with LIX 84
[Metal] in organic, g/L
[NH3] in org, ppm
pH
Cu
Fe(III)
Ni
Co
Zn
NH3
0
0.5
1
1.5
2
2.5
3
0
50
100
150
200
250
300
0
2
4
6
8
10
12

High SX transfers

>0.48 g/ L / %extractant for ammoniacal system
~0.25 g/ L / %extractant for acid system
smaller SX plant required





solvent extraction, SX

- loading
  - stage 1
    - high Cu, low free NH_3 in aqueous
      - high $2RH + Cu(NH_3)_4^{2+} = R_2Cu + 2H^+ + 4NH_3$
      - low $RH + NH_3 = RH.NH_3$
  - stage 2
    - low Cu, high free NH_3 in aqueous
      - low $2RH + Cu(NH_3)_4^{2+} = R_2Cu + 2H^+ + 4NH_3$
      - high $RH + NH_3 = RH.NH_3$
- most ammonia loads in stage 2

Ammleach®

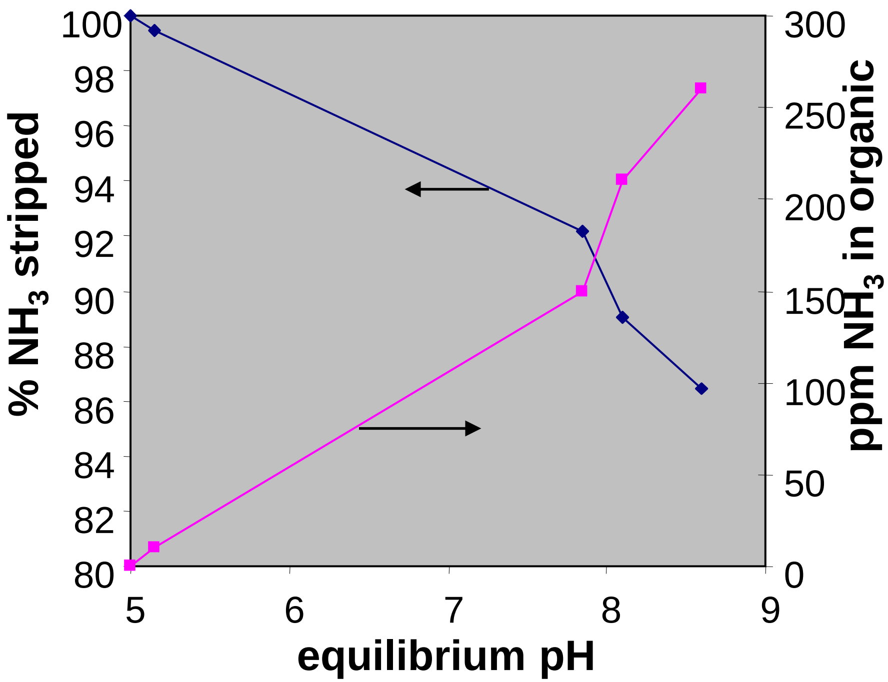
solvent extraction, SX

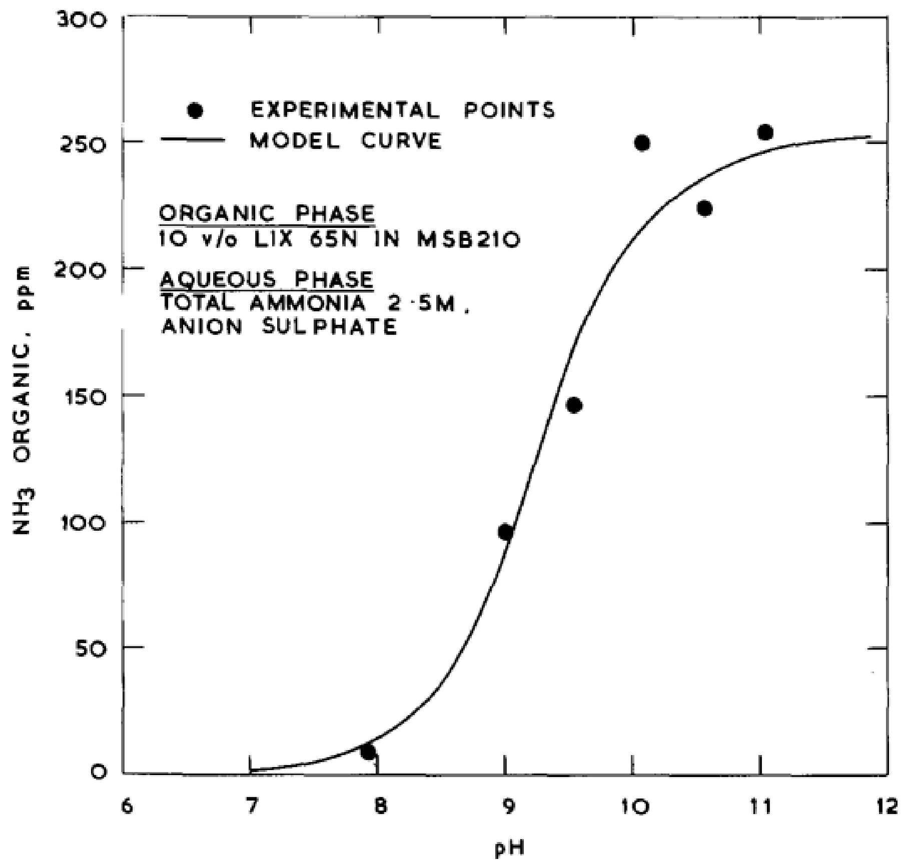
- ammonia will strip with acid
  - ammonium build-up in electrolyte
  - precipitation of ammonium sulphate

- minimise ammonia transferring to EW
  - scrubbing of loaded organic
  - minimise loading

solvent extraction, SX

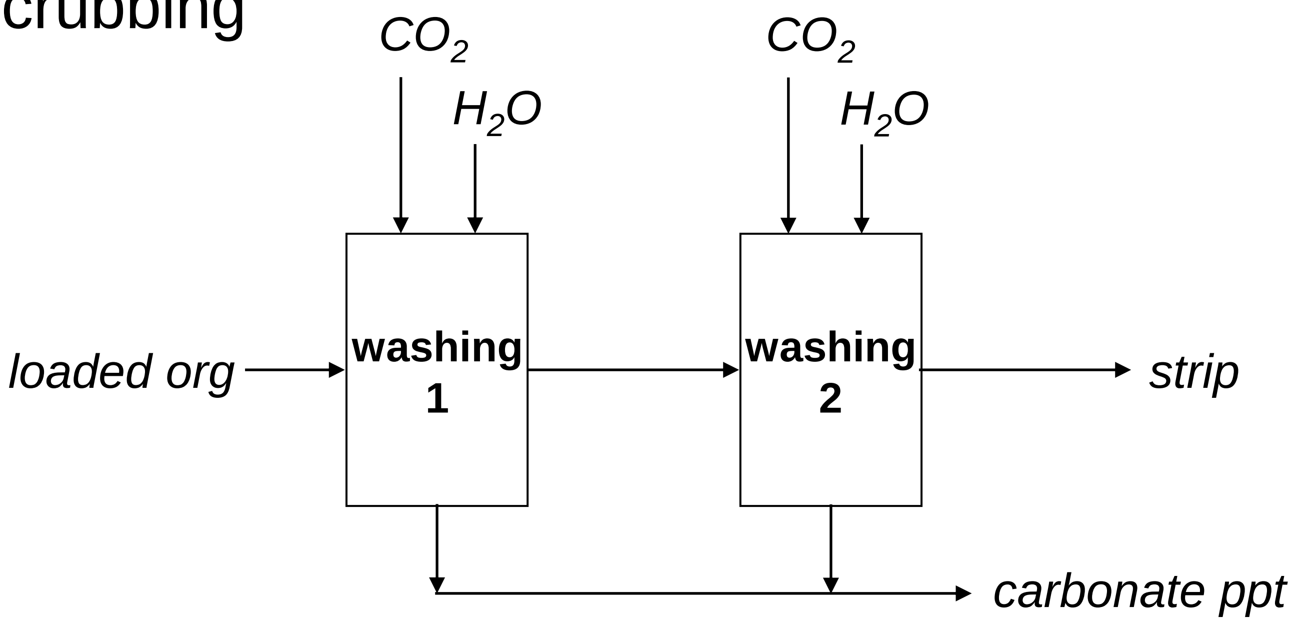
- scrubbing
  - low pH strips NH_3





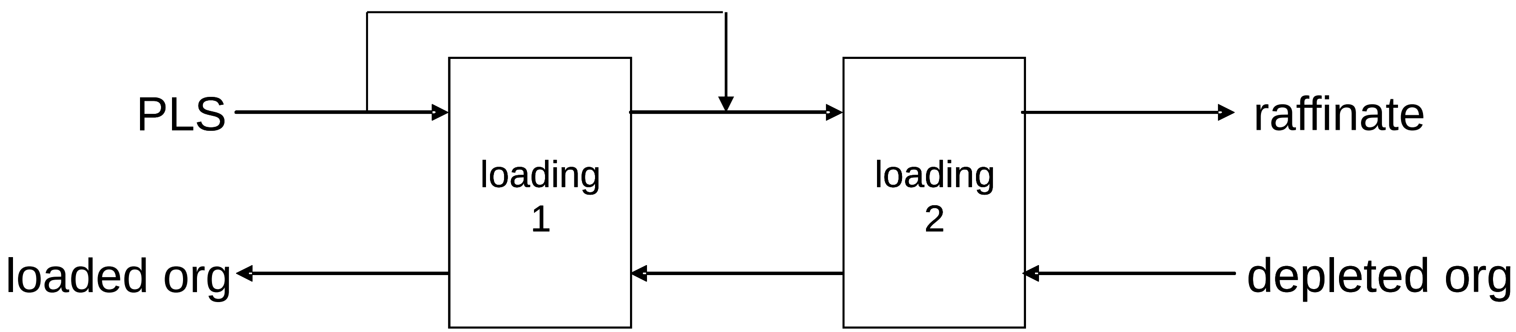
solvent extraction, SX

- scrubbing



$$CO_2 + H_2O = H^+ + HCO_3^-$$
$$RH.NH_3 + H^+ = RH + NH_4^+$$

solvent extraction, SX



$$2RH.NH_3 + Cu(NH_3)_4^{2+} = R_2Cu + 2H^+ + 6NH_3$$

Cu crowds NH_3 off the remaining extractant

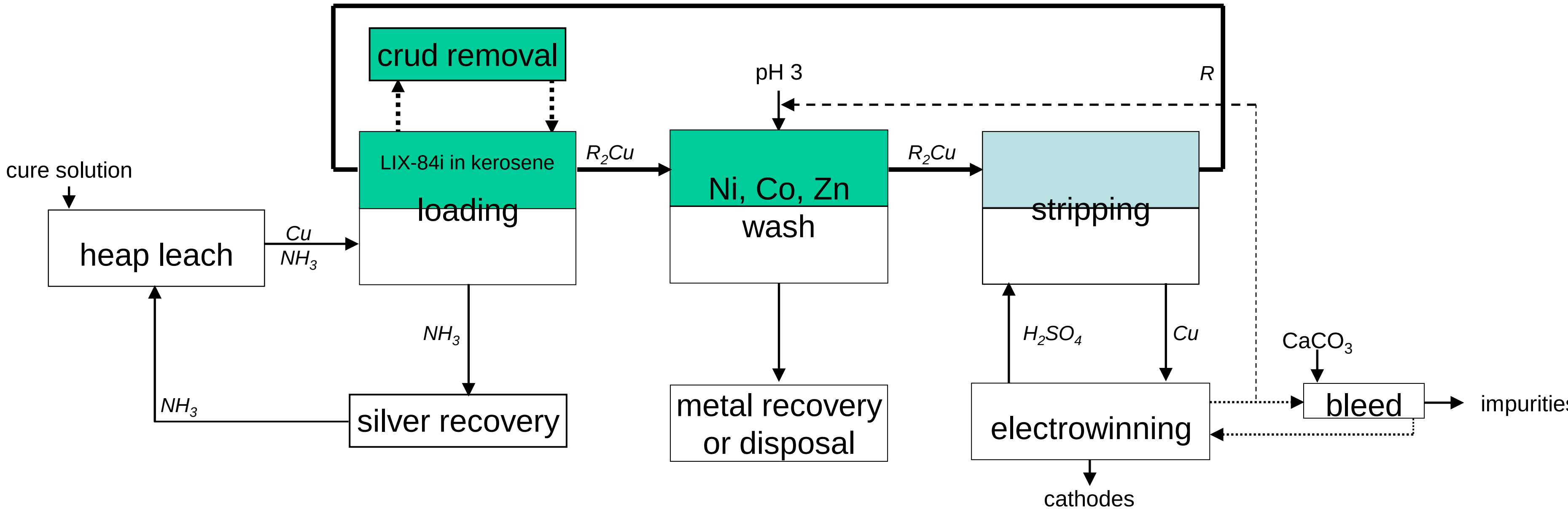
solvent extraction, SX

- scrubbing stage
  - reduced to single stage
  - now mostly defunct for ammonia
  - CO_2 storage and handling requirement reduced
    - dilute electrolyte can also be used as scrub solution
      - Cu^{2+} and H^+ both displace NH_3
      - scrub solution recycled to heap
      - removes CO_2 handling completely
  - can be used to selectively remove other metals
    - Ni, Co, Zn etc

solvent extraction, SX

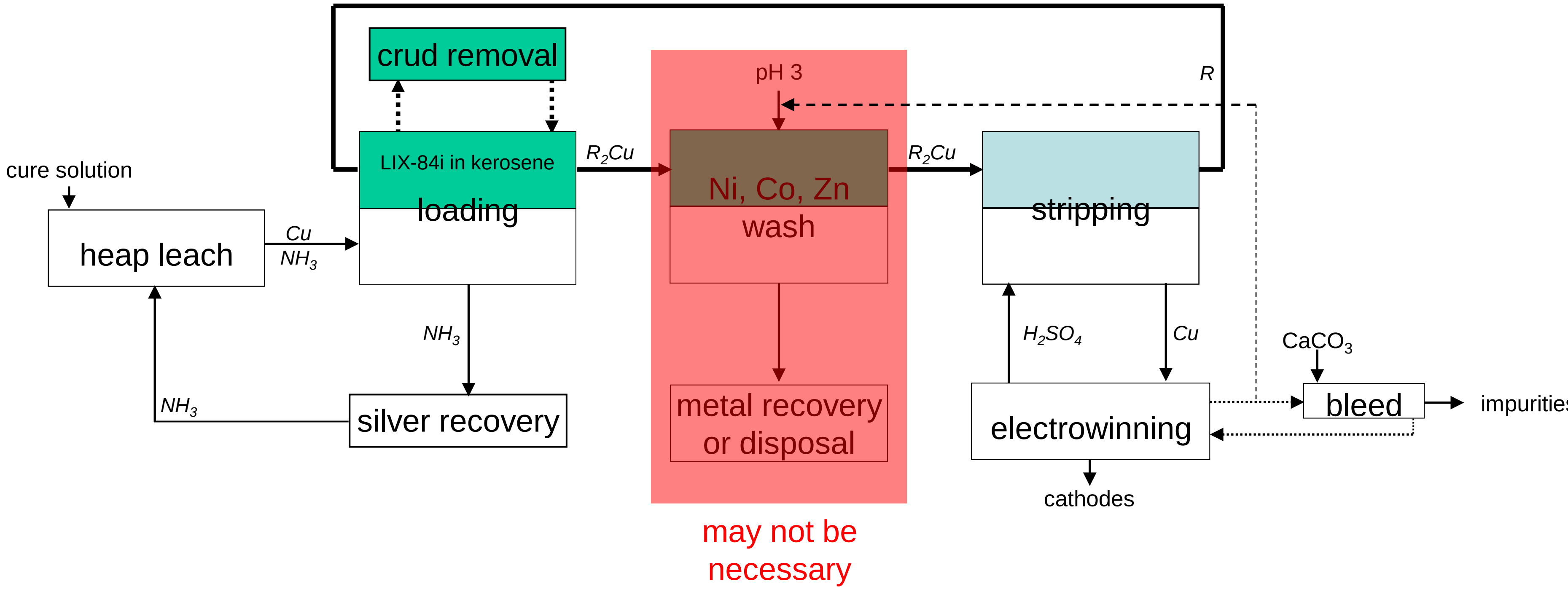
- stripping stage
  - standard spent electrolyte
    - 175 g/L H_2SO_4, 35 g/L Cu
  - loaded electrolyte
    - 150 g/L H_2SO_4, 52 g/L Cu

Flowsheet



crud removal
pH 3
R
cure solution
LIX-84i in kerosene
loading
R_2Cu
Ni, Co, Zn
wash
R_2Cu
stripping
heap leach
Cu
NH_3
NH_3
H_2SO_4
Cu
$CaCO_3$
bleed
impurities
NH_3
silver recovery
metal recovery
or disposal
electrowinning
cathodes

Flowsheet


crud removal
pH 3
R
cure solution
LIX-84i in kerosene
loading
R2Cu
Ni, Co, Zn
wash
R2Cu
stripping
heap leach
Cu
NH3
NH3
H2SO4
Cu
CaCO3
NH3
silver recovery
metal recovery
or disposal
electrowinning
bleed
impurities
cathodes
may not be
necessary

Leon pilot plant

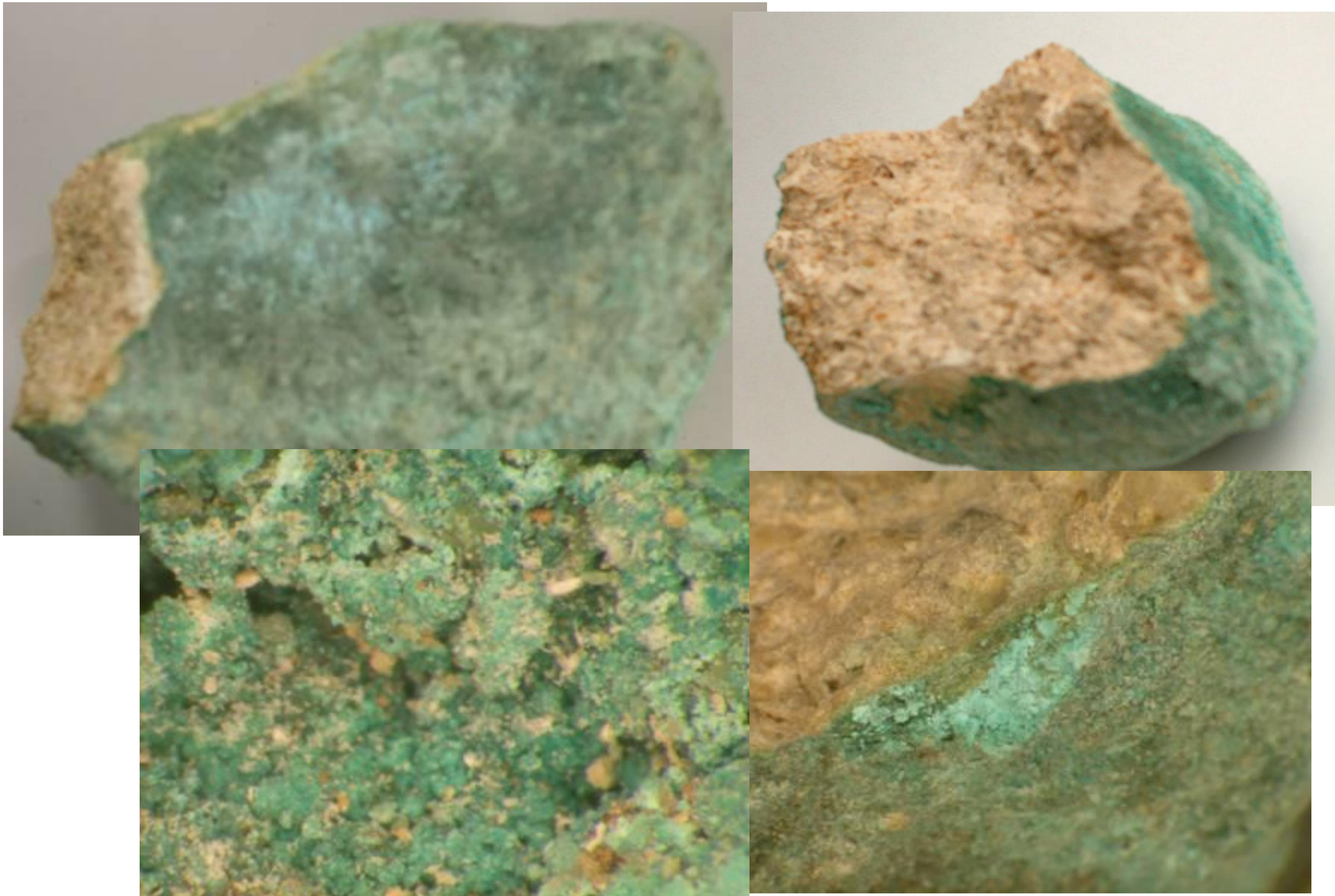
Leon pilot plant

- ore
  - 0.84% Cu / 20ppm Ag in dolomite matrix
  - 500kg H_2SO_4 / t
- 6 modules 400t each
- 150 days operation
- 50kg LME A Cu / day

Leon cure stage

- HClO – hypochlorite, 1.6 g/L
  - oxidising agent
    - Cu_2S => malachite + SO_4 + S
    - Ag => AgCl (Cl 3g/L in plant water)
    - Ag_2S => AgCl + SO_4
    - also ammonia consuming organics
- NH_3 – ammonia, 78 g/L
  - complexing agent
    - malachite => $Cu(NH_3)_4^{2+}$
    - azurite => $Cu(NH_3)_4^{2+}$
  - transports copper to surface of rocks
    - reprecipitation of malachite at surface of rocks

Ammleach®

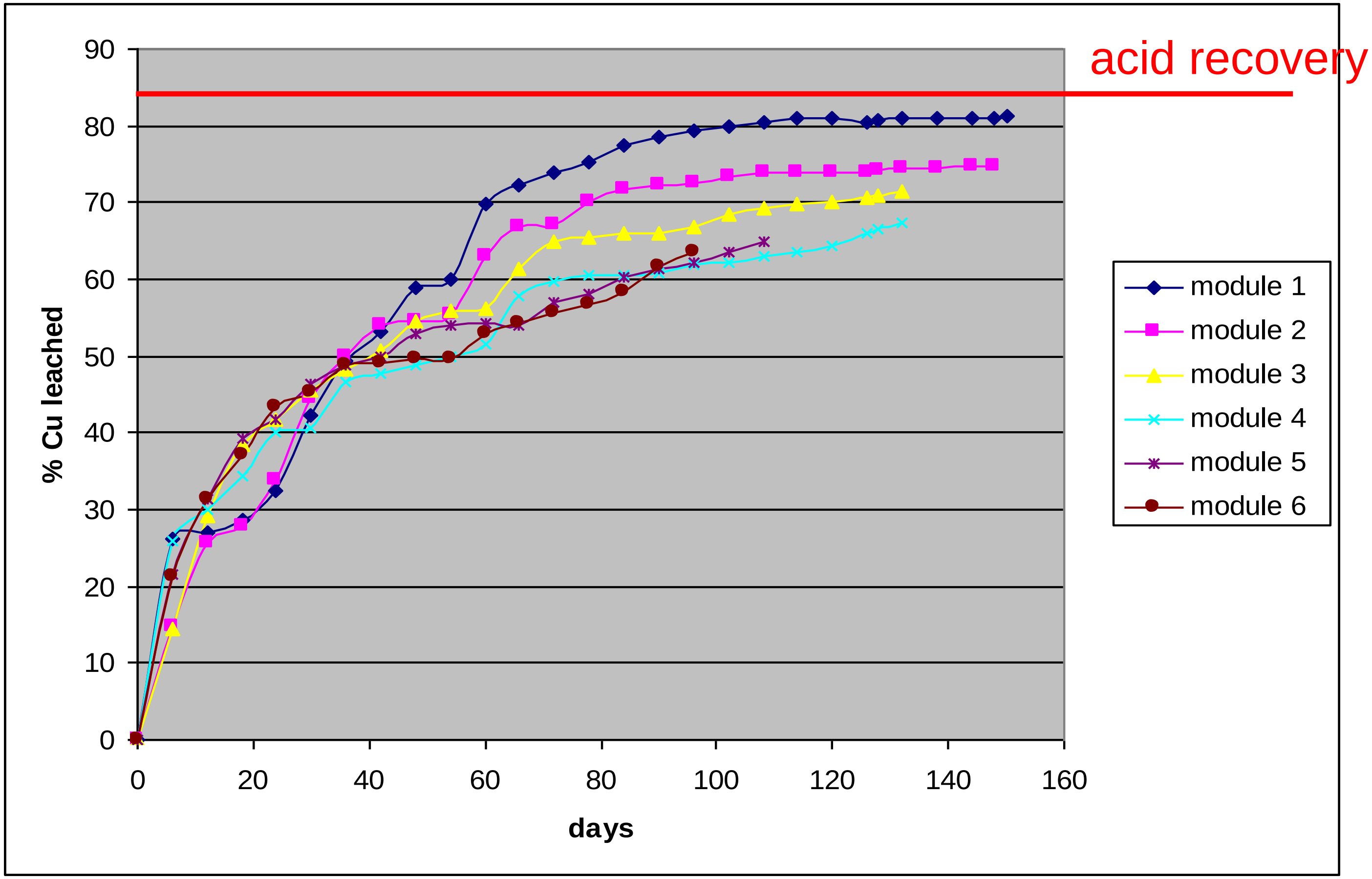


Leon leach stage

- 20g/L $(NH_4)_2CO_3$ + 10g/L NH_3
  - free ammonia matches leaching rate
    - $Cu^{2+} + 4NH_3 = Cu(NH_3)_4^{2+}$
    - 1.0 kg NH_3 = 0.93 kg Cu
  - minimal free NH_3
    - decreases losses to atmosphere
    - <1kg/t on uncovered test heap

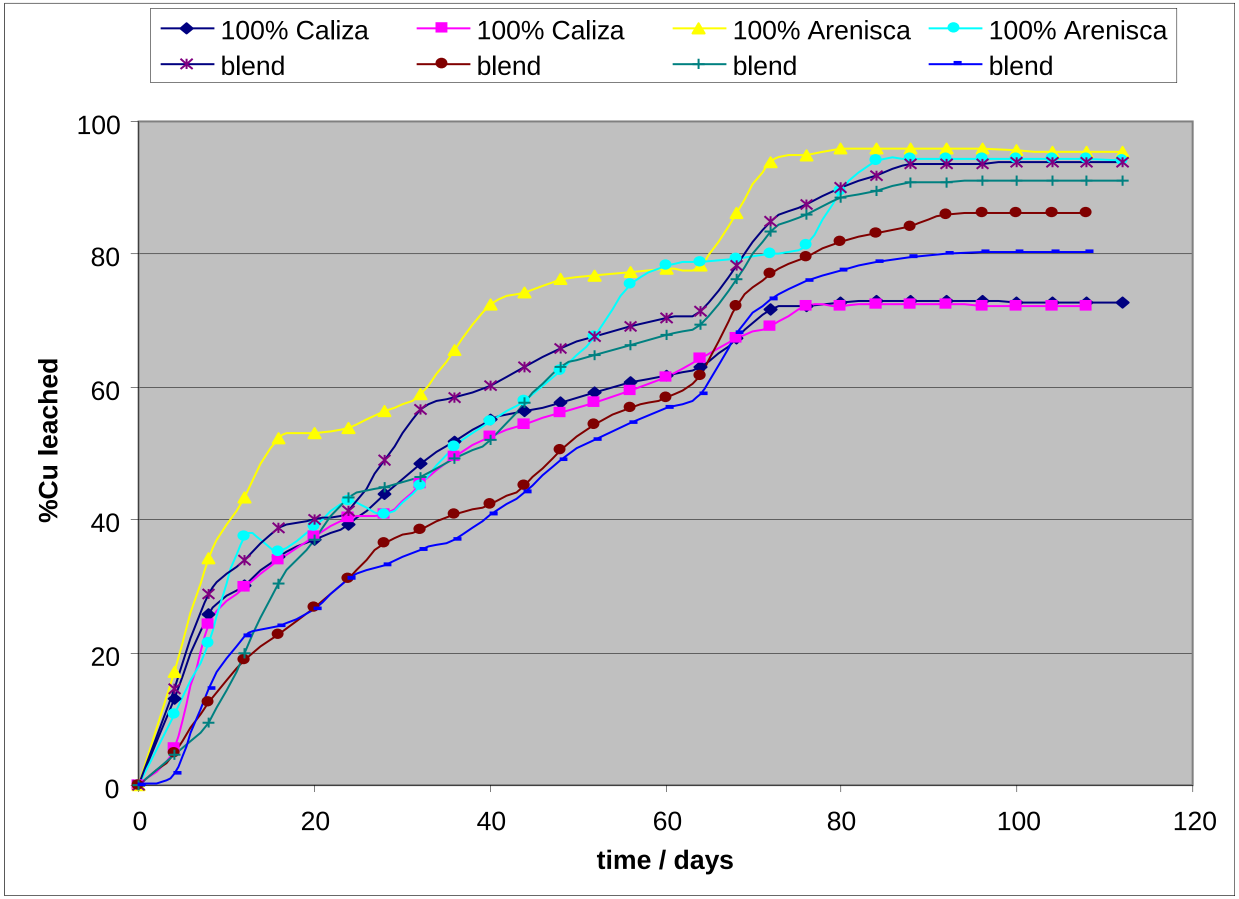
Leaching performance pilot plant II

<4” Caliza ore



Leaching performance 5m columns

<2" Caliza or Arenisca or 80/20 blend



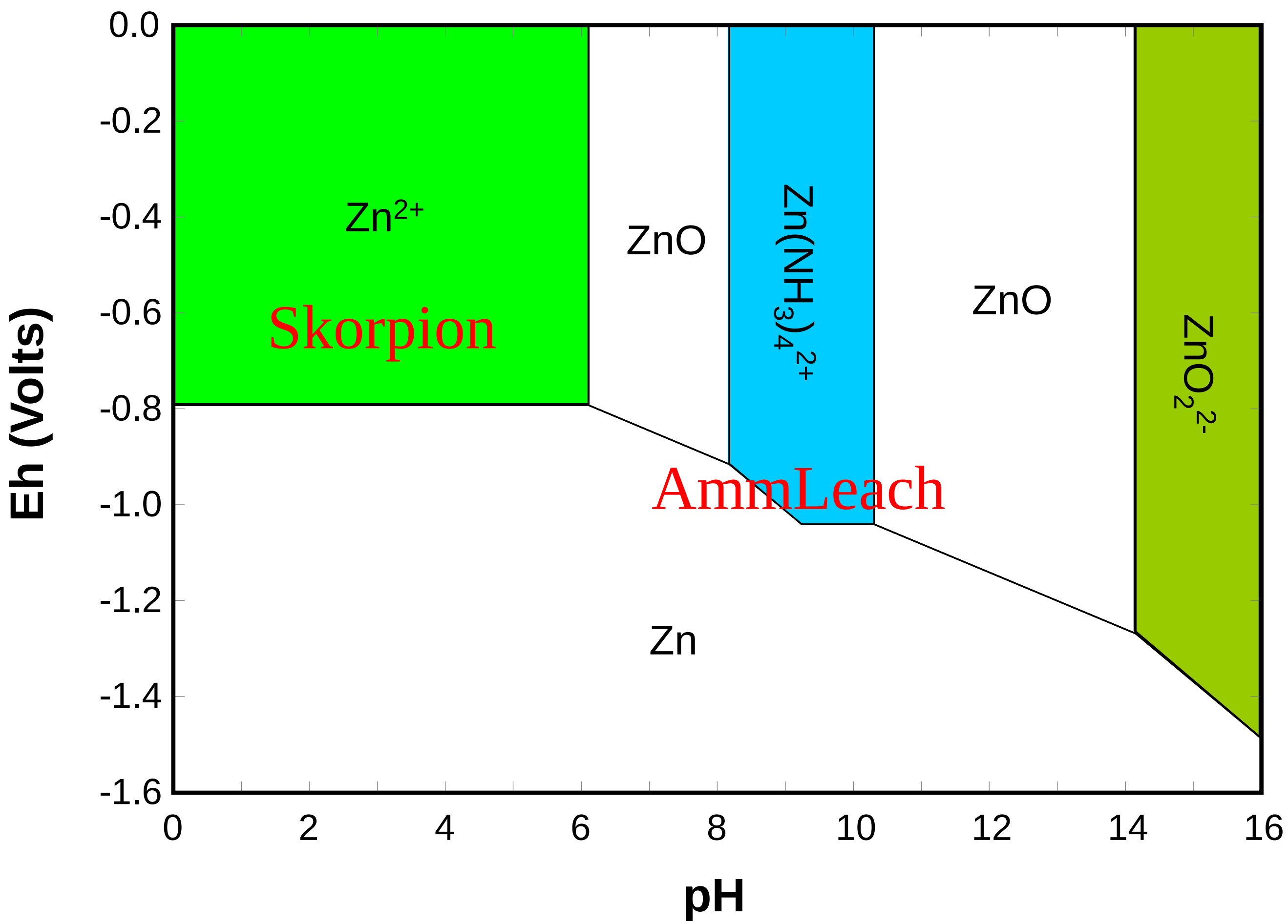
Ammleach®

Parameter	Acid	AmmLeach
mineralogy	oxides, carbonates, silicates, some sulphides	almost any– dependant upon curing stage
curing	concentrated H_2SO_4	tailored to ore mineralogy
selectivity	Low- iron, manganese, calcium and silica are likely problems	High- no iron, manganese, calcium or silica dissolution
rate of extraction	limited by acid strength and diffusion	ammonia concentration in leach solution matched to leaching rate
recovery	80% of leachable	>60% in 70 days
heap lifetime	55-480 days	~80-100 days
leachant consumption	depends upon carbonate content 3.7-27 kg/t reported	depends on concentration used <1 kg/t in preliminary pilot heap

Parameter	Acid	AmmLeach
sulphate precipitation	reduced permeability in heap, break down of clays and plant scaling due to precipitation of gypsum and jarosite	calcium and iron solubilities too low for precipitation, also low sulphate levels in leach solution
safety	concentrated acid required	gaseous ammonia main hazard, on-demand systems using hydrolysis of urea minimise transport risks
precious metals	heap to be neutralised before cyanidation	neutralisation not required, potential for simultaneous recovery using thiosulphate or sequential leaching using cyanide
decommissioning	heap requires washing, neutralisation and long term monitoring to avoid AMD	heap can be washed and left, residual ammonia acts as fertiliser for vegetation regrowth, minimal likelihood of AMD.

Oxide Zinc

Zinc solubility



Zinc mineral solubilities in AmmLeach

- >90% soluble in 1h
  - zincite ZnO
  - hydrozincite $2ZnCO_3.3Zn(OH)_2$
  - ZINC CALCINE

- >50% soluble in 4h
  - smithsonite $ZnCO_3$
  - hemimorphite $H_2Zn_2SiO_5$

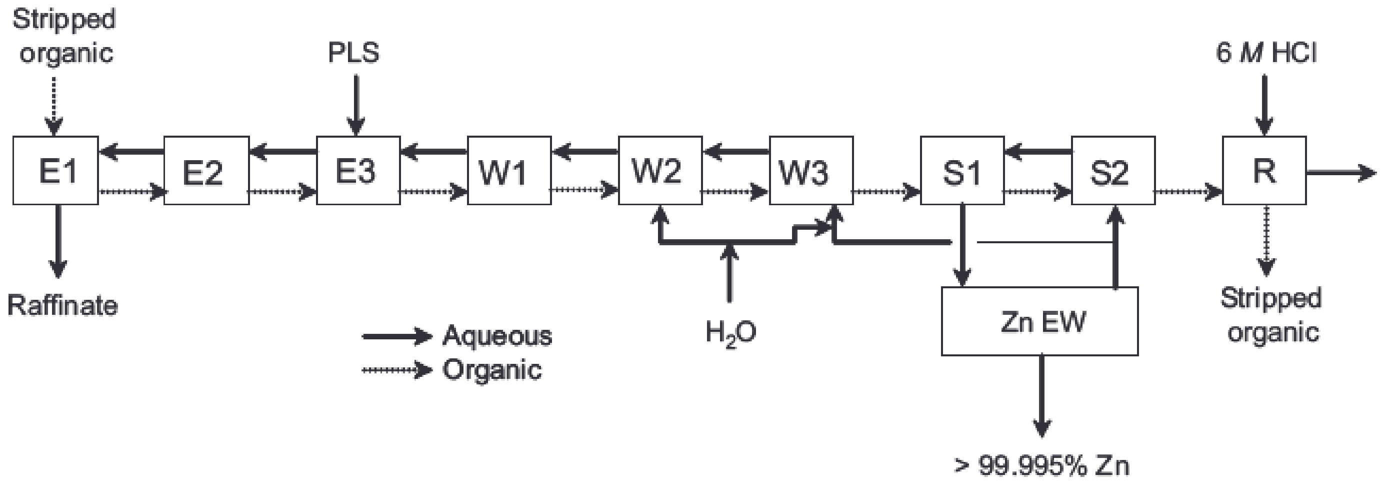
- <10% solubility in 168h
  - franklinite, $ZnFe_2O_4$
  - willemite Zn_2SiO_4
  - sphalerite, ZnS **NOTE: with appropriate curing ZnS can be completely solubilised

Solution purity for EW

Cu mg/l	< 0.2
Cd mg/l	< 2
Pb mg/l	0.2 – 2.0
Co mg/l	<0.5
Ni mg/l	<0.1
As + Sb mg/l	<0.1
Cl mg/l	50 - 200
F mg/l	1 - 20

difficult to achieve purity with SX

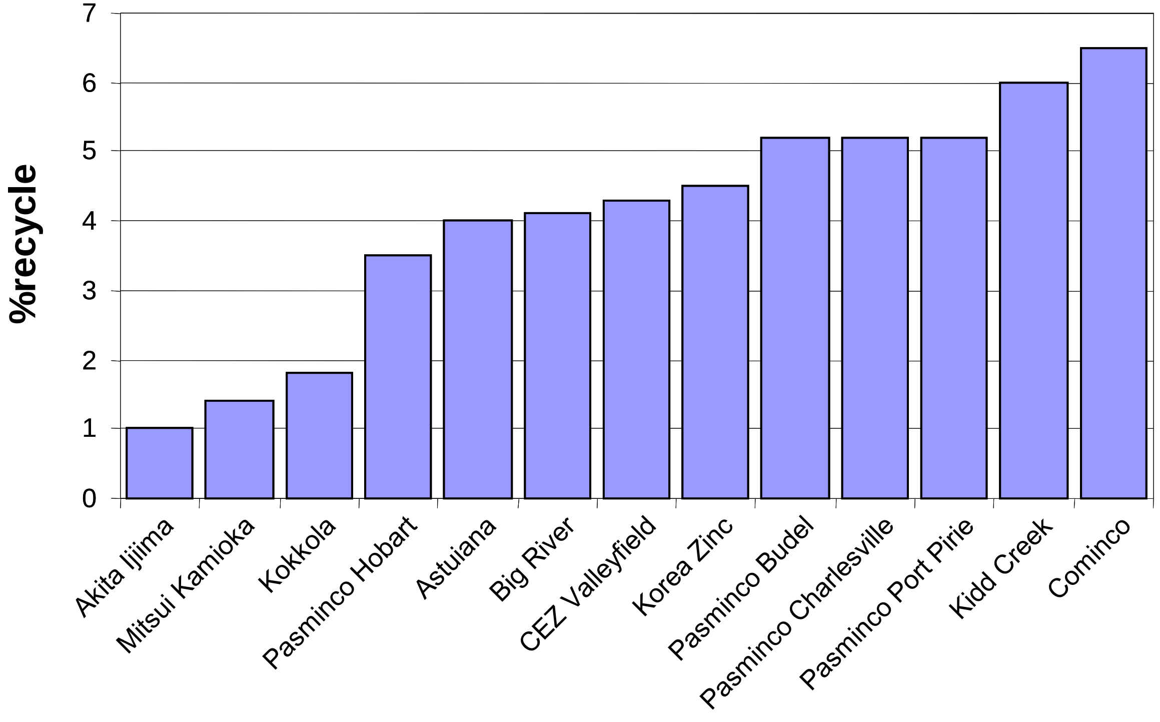
- Skorpion, Namibia
  - multistage SX to clean solution for EW



difficult to achieve purity with SX

RLE processes use cementation

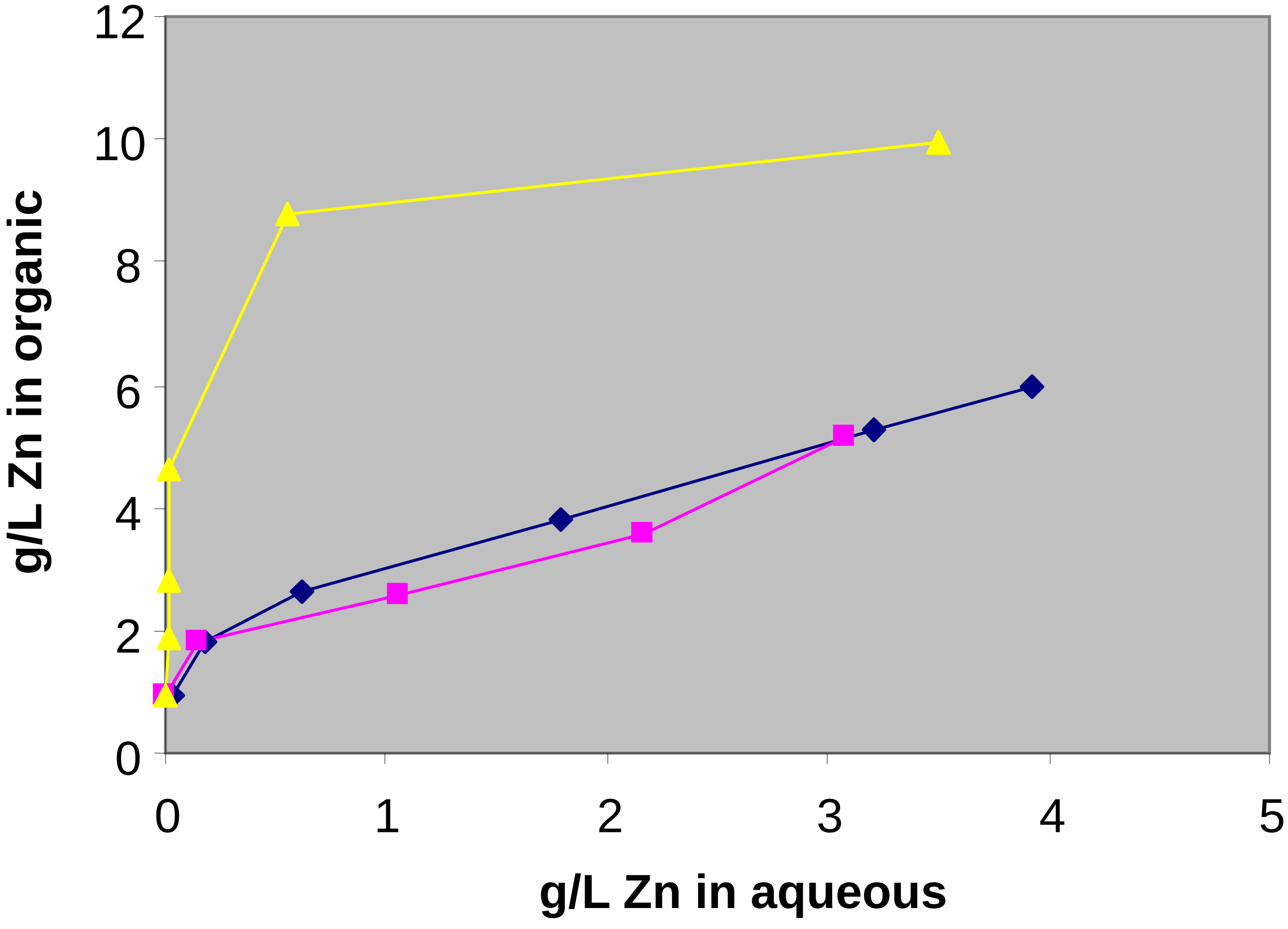
- Zn recycled



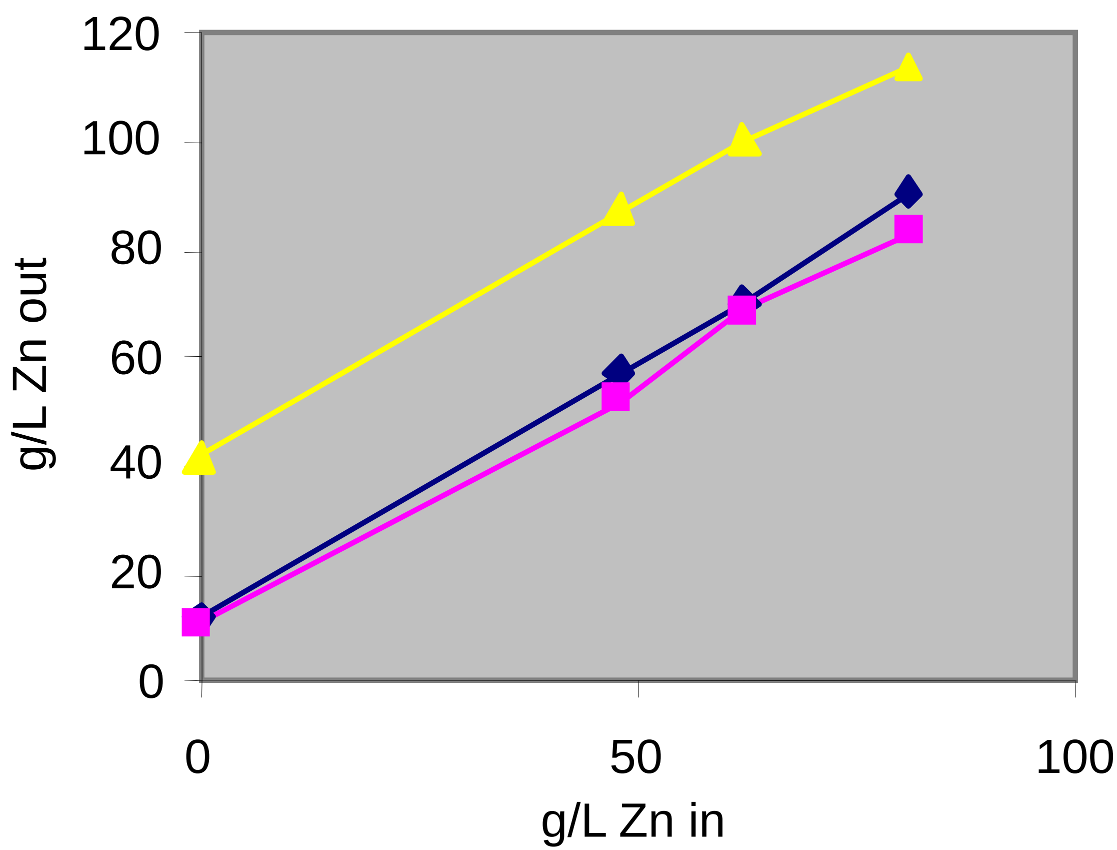
element	acid	AmmLeach	NOTES
Zn	✓	✓	
Cd	✓	✓	most removed during SX
Fe	✓	✗	ppts
Si	✓	✗	insoluble
Co	✓	✓	most removed during SX
Ni	✓	✓	most removed during SX
Cu	✓	✓	most removed during SX
Ge	✓	✗	sorbs onto iron ppt
As	✓	✗	sorbs onto iron ppt
Sb	✓	✗	sorbs onto iron ppt
Pb	✓	✗	insoluble
Cl	✓	?	under investigation
F	✓	?	under investigation

Zinc solvent extraction

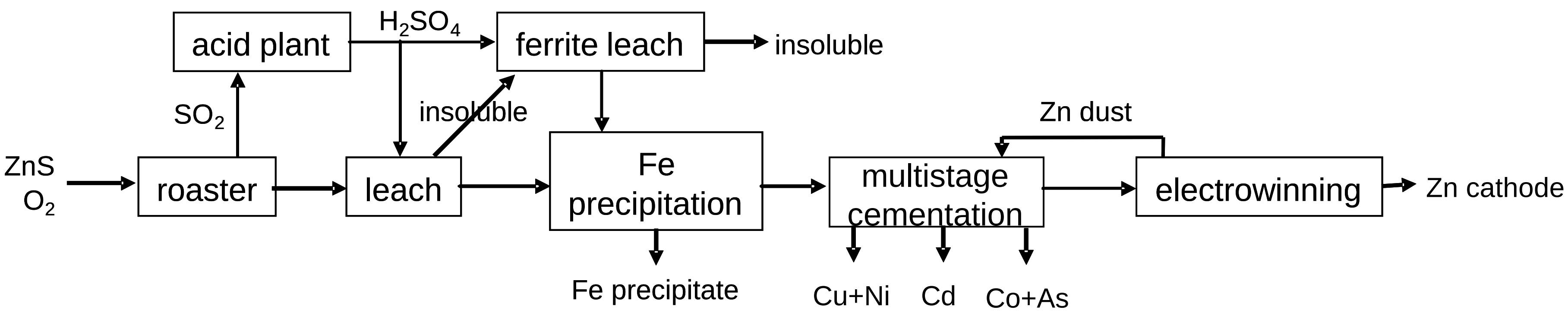
• zinc SX from ammoniacal solution



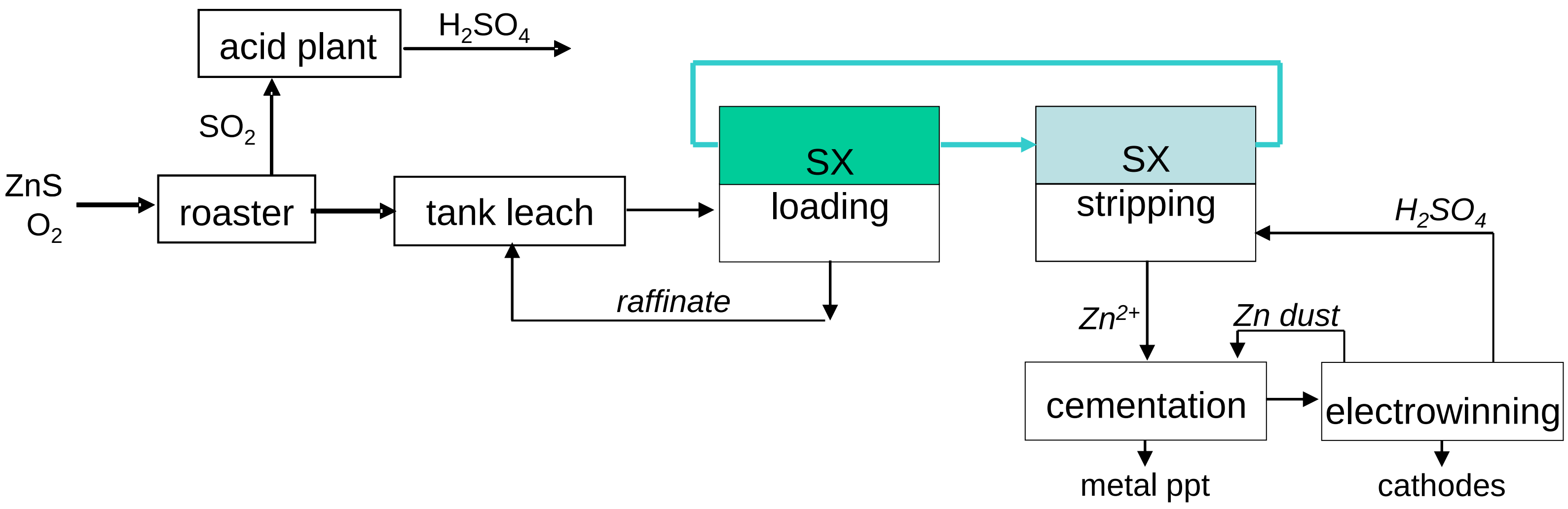
- acid stripping of zinc from organic loaded using ammoniacal solution



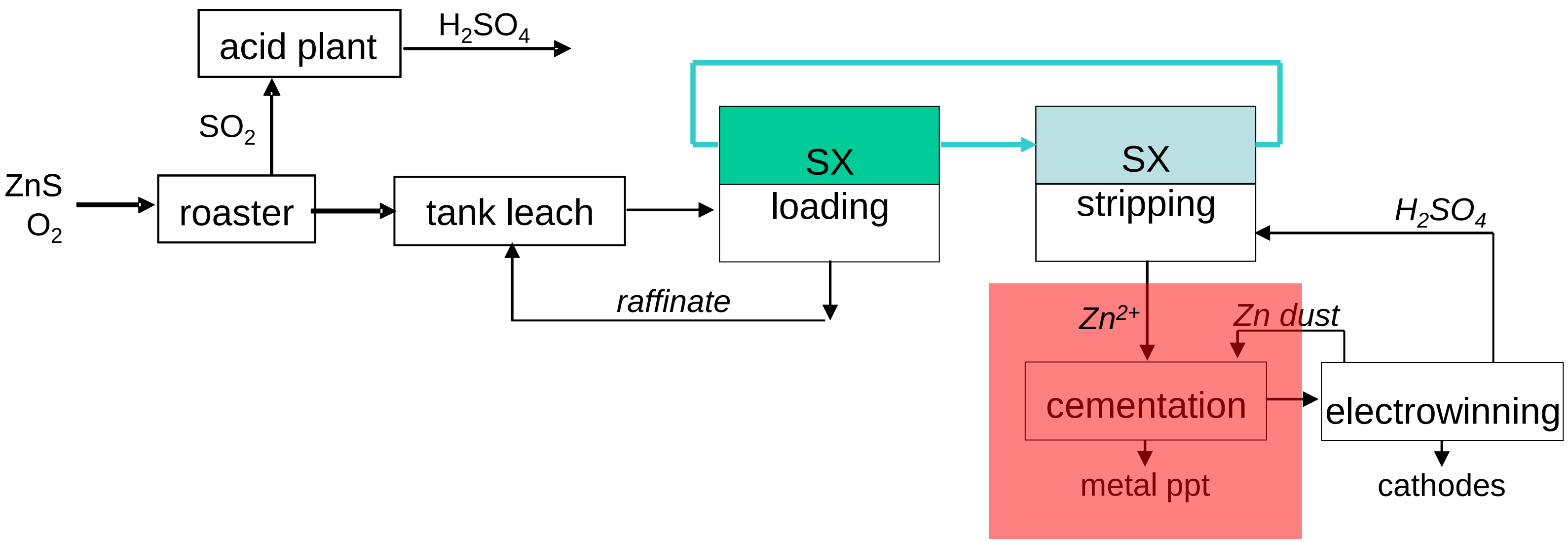
Current RLE flowsheet



AmmLeach RLE flowsheet



AmmLeach RLE flowsheet



not required
or bleed

Parameter	Acid	AmmLeach
mineralogy	oxides, carbonates, silicates, some sulphides	oxides, carbonates, silicates, some sulphides
curing		ore specific - likely to be none
selectivity	low - iron, manganese, calcium and silica are likely problems	high - no iron, manganese, calcium or silica dissolution
rate of extraction	limited by acid strength and diffusion	ammonia concentration in leach solution matched to leaching rate
sulphate precipitation	reduced permeability in heap break down of clays and plant scaling by gypsum and jarosite	calcium and iron solubilities too low for precipitation, also low sulphate levels in leach solution
leachant consumption	ore dependant	reagents are recycled and losses are very low
solvent extraction and stripping	requires considerable solution manipulation, involving cementation/precipitation to remove iron, manganese and calcium because of low selectivity for zinc extraction into the organic phase	highly selective for zinc and significant advance of previously reported extraction efficiencies
safety	concentrated acid required	gaseous ammonia main hazard, on-demand systems using hydrolysis of urea minimises transport risks

Other applications

- nickel and cobalt from lateritic deposits;
- gold, silver and copper in leached porphyries;
- polymetallic base metal deposits, especially U;
- leaching of metals from roaster concentrates;
- preleaching copper from copper-gold ores

Hyperleach™

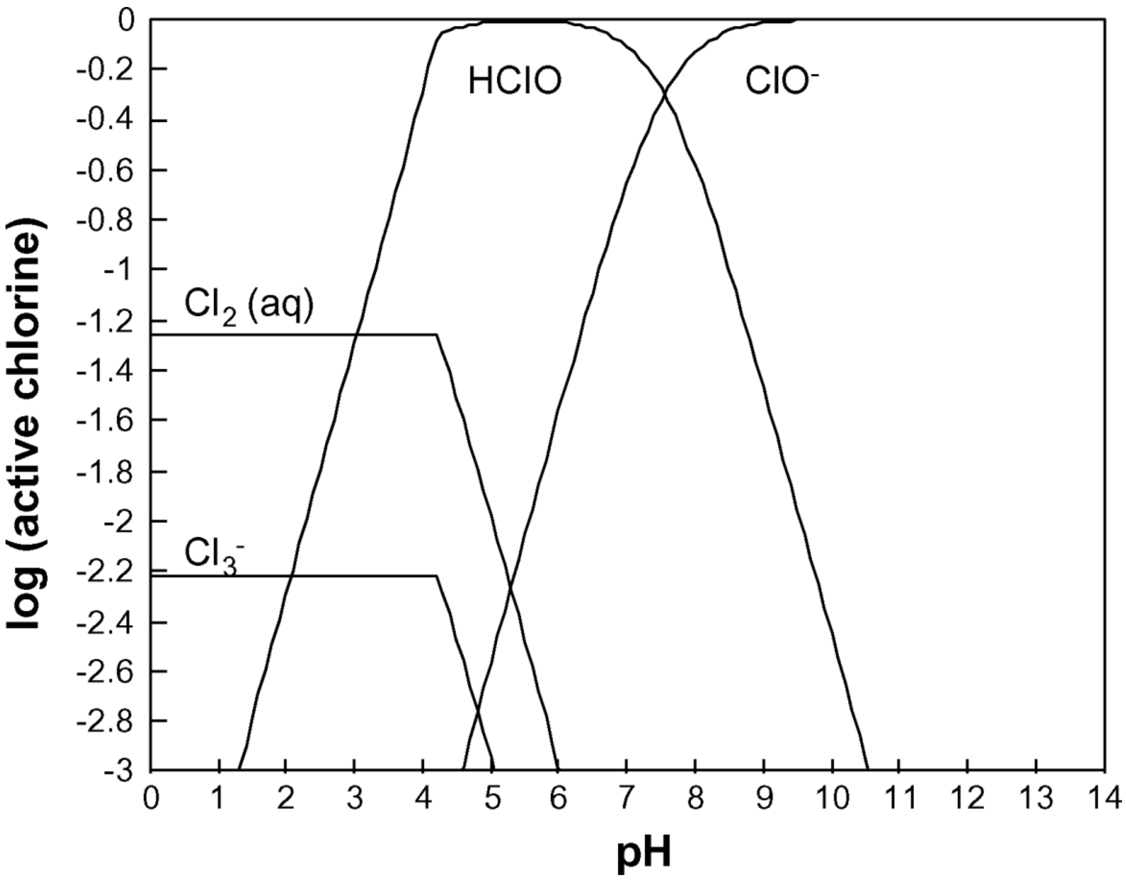
Hyperleach™

KEY FEATURES

- leaches base metal sulphides including
  - chalcopyrite, bornite, chalcocite, enargite
  - millerite, pentlandite, pyrrhotite, violarite
  - sphalerite

- ambient temperature
- ambient pressure
- heap leach or tank leaching
- rapid kinetics
- selective for sphalerite over galena
- selective for Ni-sulphides over pyrite
- low reagent consumptions

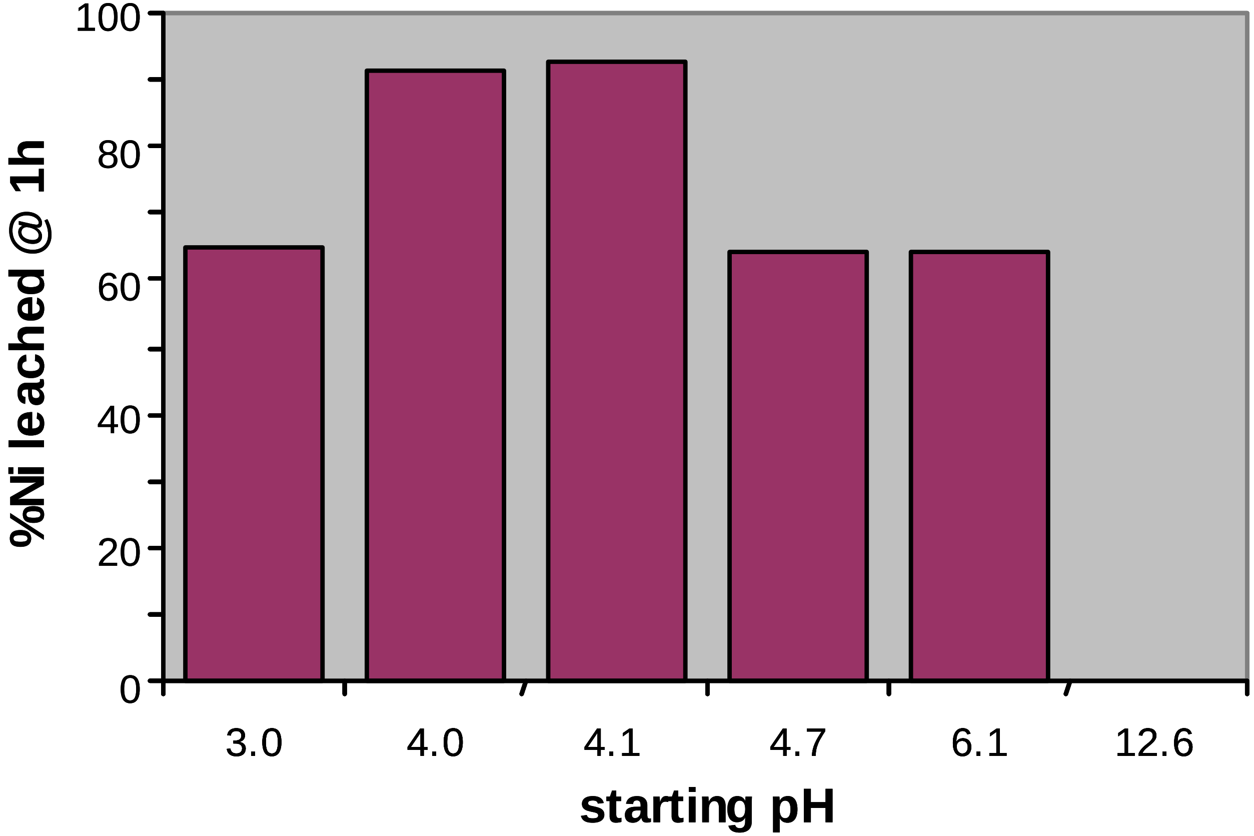
Controlled pH increases oxidant concentration tenfold



Nickel

Nickel

pentlandite / pyrrhotite flotation concentrate (15% Ni)



Nickel

reagent consumption

	Head-grade %Ni	% leached Ni	% leached Fe	mass loss %	kg Cl_2 / kg Ni
pentlandite / pyrrhotite specimen	10	93.7	61.1	39.7	4.6
low grade ore	1.6	85.7	0.0	2.5	4.8

NOTE: careful control of the pH for the low grade ore resulted in complete iron precipitation.

Hyperleach™

Nickel

post-leach options

Option	CAPEX	OPEX	complexity	Notes
selective ppt as hydroxide	low	low	low	hydroxide sold to existing refinery, e.g. BHPBilliton's Yabulu
iron ppt, Ni/Co SX, ppt as separate hydroxide / sulphide	medium	medium	medium	high grade intermediates sold to existing refinery
iron ppt, Ni/Co SX, metal EW	high	high	high	complex flowsheet

Nickel

other processes

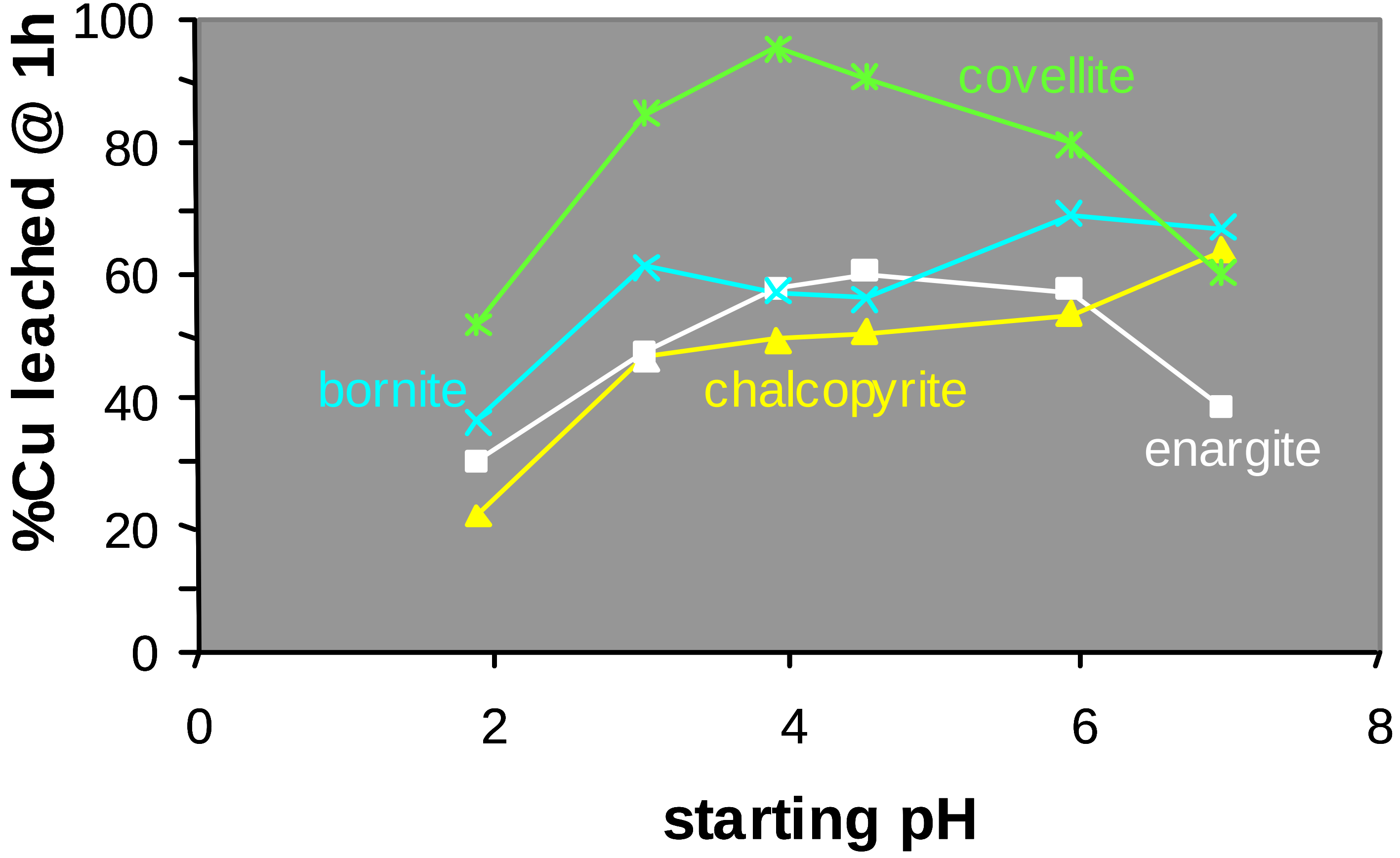
Process	Developer	Feed %Ni	P_{80} (µm)	temp (ºC)	pressure atm	Notes
BioNIC	BHP Billiton	4–12	75	30–40	1	dilute H_2SO_4 and bacteria
Intec Ni	Intec	3–6	25	80–90	1	aeration, acid pre-leach, and Br/Cl leach
Activox	Western Min. Tech.	4–12	10	100	10	O_2
CESL Ni	Cominco	8–15	45	150	14	O_2, HCl
Sherritt Gordon	Sherritt	20–70	75	150	10	matte leach using NH_3 and O_2
HyperLeach	**Alexander**	**0.7-70**	*	**25**	**1**	**works on low grade ore, concentrates and matte**

* varies with feed

Copper

Copper

minerals



Copper

reagent consumption

	Head-grade %Cu	leached %	mass loss %	solution tenor g/L	kg Cl_2 / kg Cu
chalcopyrite / bornite conc	26.6	54	43.8	1.4	3.5
chalcopyrite conc	29.1	51	40.1	1.5	3.3
covellite	79.3	72.8	70.5	5.8	0.6
low grade chalcopyrite ore	3.18	>99	3.1	0.35	7.9

NOTE: the high consumption for the low grade chalcopyrite was due to host rock being a carbonaceous shale.

Copper

other processes

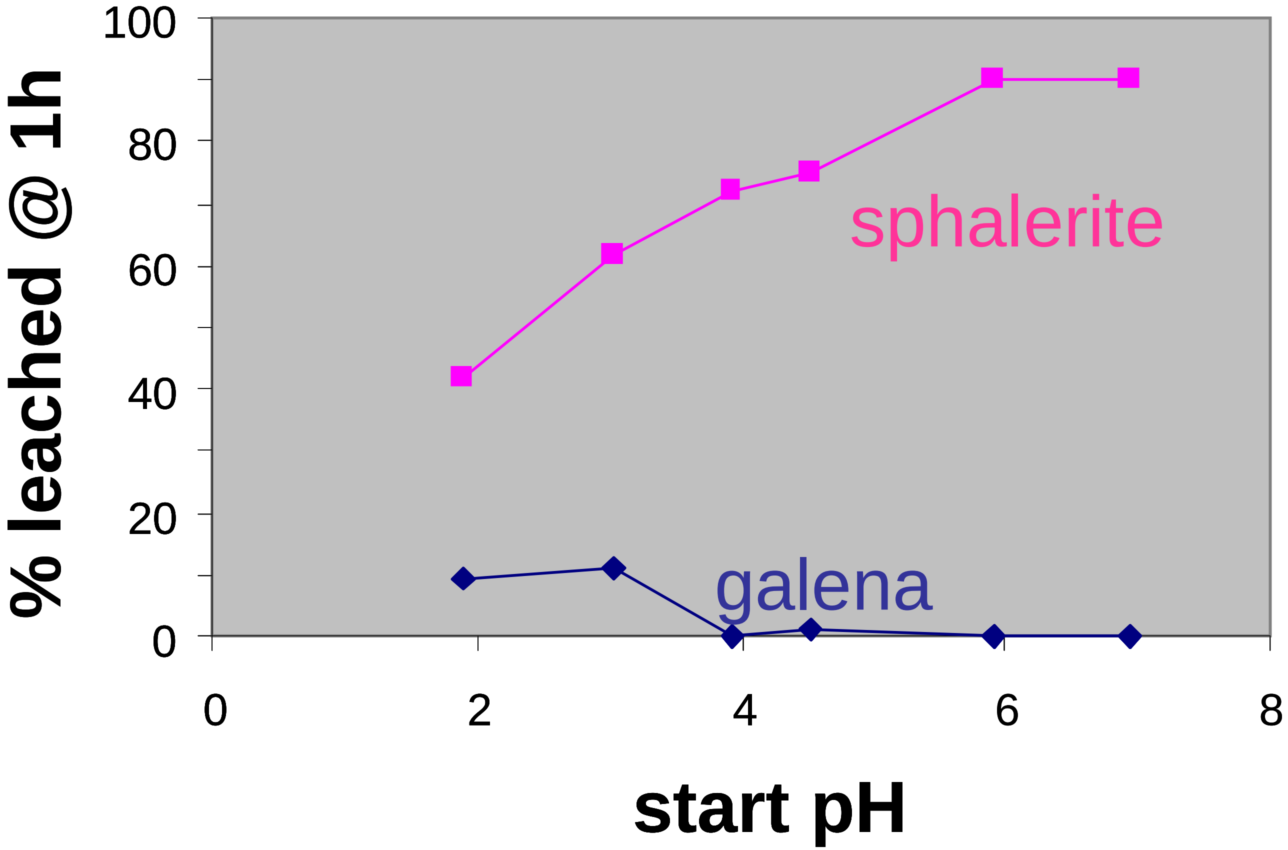
Process	Developer	^oC	pressure	P_{80} µm	notes
Activox	XstrataNickel	110	9	<10	high oxygen overcomes chalcopyrite passivation
Albion	XstrataTech	85	1	<10	ferric chloride leaching
UBC / AARL	UBC / AARL	150	10-12	<15	surfactants used to overcome elemental sulphur
Galvanox	UBC/ Bateman	80	1	75	pyrite recycle aids chalcopyrite leaching
BioCop	BHPBilliton	80	1	22	thermophilic bacteria used
Bioleach	numerous	35-50 65-75	1 1	5-20 37	very fine grind essential uses thermophilic bacteria
CESL	Cominco	165	15	37	chloride catalysed
Dynatec	Sherritt-Gordon	150	13	37	low grade coal used to control elemental sulphur
Total POx	Phelps-Dodge	200-230	30-40	53	extreme T and P - indiscriminate
Hydrocopper	Outokumpo	85-95	1	n/a	250-300g/L NaCl
Intec Copper	Intec Ltd	85-95	1	n/a	mixed Br/Cl leachant
HyperLeach	**Alexander**	**25**	**1**		**optimum grind size to be determined**

Hyperleach™

Lead - zinc

Lead – zinc

minerals



Lead – zinc

concentrate cleaning

	headgrade %	**leached %**	**residue % (calculated)**
Zn	5.45	87.2	0.93
Cu	3.4	64.2	1.63
Pb	52.23	1.7	68.7

Other applications

HEAP LEACHING

- nickel sulphide ores
- copper sulphide ores
- native copper ores
- mixed copper sulphide / oxide ores
- copper-gold ores
- uranium
- molybdenum sulphide / oxide

TANK LEACHING

- nickel sulphide concentrates
- nickel mattes
- copper flotation concentrates
- arsenical copper ores
- arsenical gold ores
- gold bearing sulphides
- concentrate cleaning
- PGM bearing sulphides / matte
- molybdenum sulphide

Hyperleach™

Costs

Mineral	Range of Hypochlorite Operating costs US$/lb metal produced
chalcopyrite $CuFeS_2$	$0.45-$0.90
pentlandite $(Ni,Fe)_9S_8$	$0.60-$1.20
sphalerite ZnS	$0.40-$0.90

These costs are based upon chlorine costs of US$300-600 per tonne.

Summary

- leaches base metal sulphides including chalcopyrite, bornite, chalcocite, millerite, pentlandite, pyrrhotite, violarite, sphalerite and enargite;
- rapid kinetics at ambient temperatures and pressure;
- suitable for heap leaching as well as tank leaching;
- does not require chlorine gas to operate;
- oxidant generated on-demand and on-site via chlor-alkali technology; low reagent consumption;
- polymetallic deposits can be readily handled using standard solvent extraction and solution purification techniques; and
- less environmentally harmful than smelting