



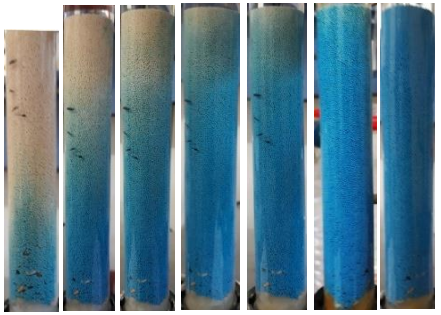

Economic potential of reprocessing copper mine tailings in a small to medium scale

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GEOZENTRUM HANNOVER

BGR Projects

- **Project AHK 2013 – 2015**
  - 12 tailings sampled and analysed
  - Processing tests on 4 tailings

- **Project SERNAGEOMIN 2016 – 2020**
  - 10 tailings sampled and analysed
  - Processing tests on 2 tailings
  - Detailled processing on 1 tailing

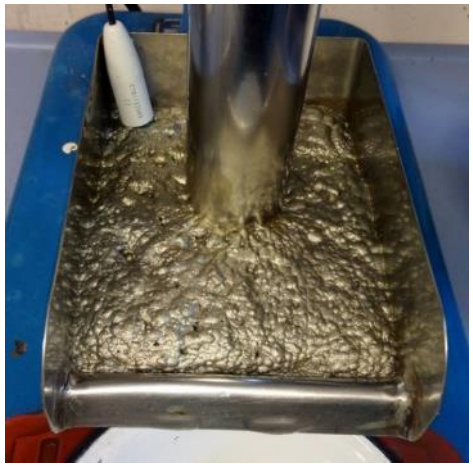
Muestreo con sonda (Tranque Delirio, Punitaqui)

Acesso de relaves de SOTRAMIN (Taltal)

Saca de la sonda con barras (Tranque Delirio, Punitaqui)

General proceding in economic evaluation

- To evaluate tailings several processing options have to be be evaluated
  - Flotation,
  - Gravimetric separation,
  - Magnetic separation,
  - leaching
  - Copper recovery from leaching solutions



Prueba de flotación

Concentrado de magnetita

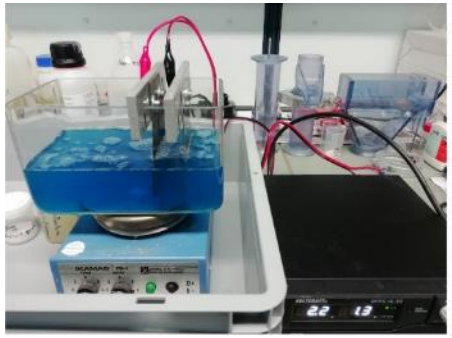
Pruebas de lixiviación con ácido sulfúrico

General proceding in economic evaluation

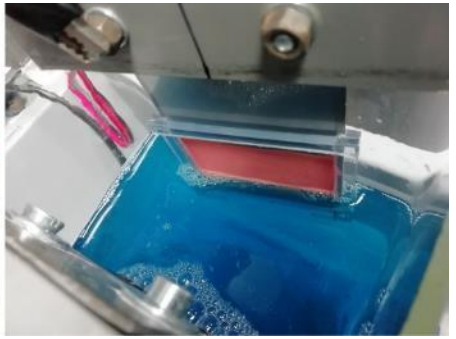
– Cost models adopted to reprocessing of tailings were developed, in order to estimate investment and operating costs and to evaluate the feasibility of reprocessing the tailings

Separación magnética

Separación de la solución



Electrólisis



Electrólisis

Example of results (Taltal)

	Las Luces I	Las Luces II	Sotramin	ENAMI	Paposo
Tonnage [Mil. t]	5,2	9,5	0,1	2,0	2,1
Average Cu grade [%]	0,12	0,28	0,29	0,56	0,33
Average Fe grade [%]	8	11	6	26	32
Average As grade [ppm]	2	56	70	87	38
Perforations	8	6	8	16	8
Total meters	56	52	35	122	59

Processing tests (Taltal)

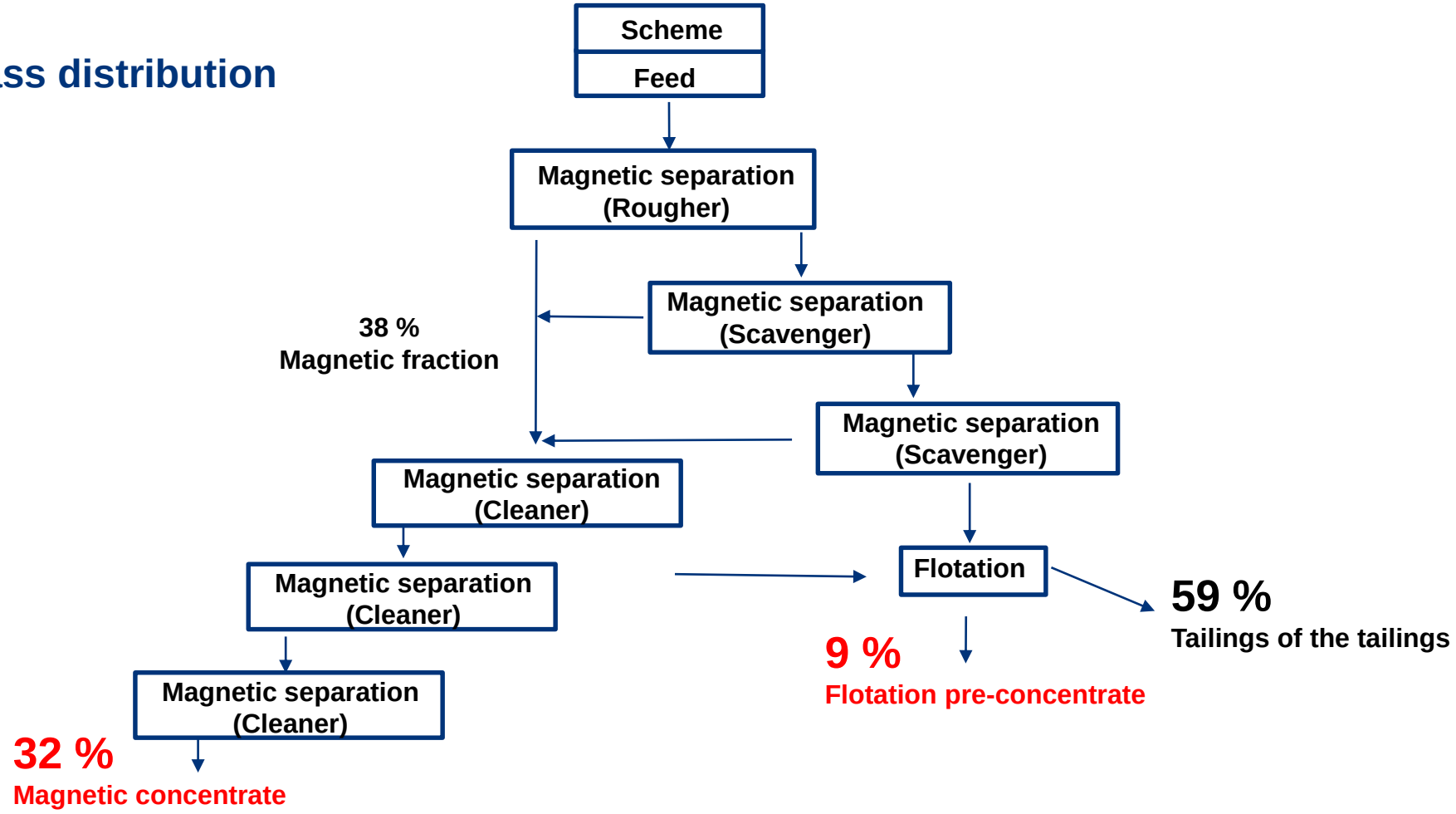
- Not only copper can be of interest, but especially iron grades can be interesting. Especially in the iron-belt (roughly from Taltal to Copiapo and further to La Serrena
- In Taltal, Fe grades in sample from Taltal up to 36 % (average 26 %)
- Cu grades up to 1,0 % (average 0,5 %),

- Other value elements like the so called critical elements are very scarce

Flow diagrams for reprocessing

Magnetic separation followed by flotation

Mass distribution



Simplified estimation of the feasibility of reprocessing

Simplified valorisation

Flotation – mag. sep.	Mass [t]	grade Fe [%]	rec Fe [%]	grade Cu [%]	rec Cu [%]	Cu cont [t]	Metal* value [US$]
Tailings total	2.000.000	26		0,56			
Pre-conc. Cu	430.000			1,5	59	6.580	36.200.000
Fe concentrate	570.000	60	64	0,08			37.000.000

- Good Fe recovery, poor Cu recovery.
- Investment and processing costs: 36 Mio. US$
- Non marketable Cu-product

Flotation 500 t/d*					
	labour	supplies	administration	diverse articles	Total
Original processing costs	7,61	8,68	3,69	2,02	22,27
CAPEX					15.700.000
Without crushing and milling					
Processing costs	4,19	2,78	2,61	1,33	10,91
CAPEX					8.400.000
including contingency					
Adopted Processing costs					**13,36**
Adopted CAPEX					**9.400.000**

Total investment plus processing costs	**36.120.000**
t of Cu to be recovered	**6.567**
including NSR of 0.8	**8.209**
recoverable Cu grade	**0,41**

*costs from CostMine

*Precios: Fe 65 US$/t, Cu 5.500 US$/t

Simplified valorisation

Leaching – mag. sep.	Mass [t]	grade Fe [%]	rec Fe [%]	grade Cu [%]	Cu-leach [%]	Cu Rec [%]	Cu-cont [t]	Metal* value [US$]
Tailings total	2.000.000	27		0,5			11.200	
Leaching	2.000.000				0,4	80	8.000	44.000.000
Fe concentrate	600.000	60	74					39.000.000

- Much higher Cu recovery
- Marketable product

Agitated tank leaching 500 t/d				
Processing costs	labour	supplies	Operation and equipment	Total
Original processing costs	**22,23**	**13,55**	**4,26**	**40,04**
CAPEX				**19.460.700**
Without crushing and milling				
Processing costs	**12,16**	**10,39**	**2,83**	**25,38**
CAPEX				**16.714.180**
Without crushing and milling AND adaption of Cu leaching				
Adopted Processing costs	**8,15**	**5,865**	**2,155**	**16,17**
Adopted CAPEX				**9.400.000**

Total investment plus processing costs		**41.200.000**
t of Cu to be recovered		**7.490**
~~including NSR of 0.8~~		**7.409**
recoverable Cu grade		**0,37**

*cost from CostMine

*Precios: Fe 65 US$/t, Cu 5.500 US$/t

Economic evaluation using adopted cost models

Economies with adopted “agitation leach” model:

	Mass tailings [t]	Cu grade in tailings [%]	Cu recovery [%]	Cu recovery [t]	Metal value* [US$]	Costs of recovery [US$]
leaching	2.000.000	0,5	80	8.000	44.000.000	41.200.000

- Costs are covered by revenue
- With a 500 t/d capacity -> 12 years to reprocess the tailings
- Comparable mining project would have optimum lifetime of 6-7 years -> 500 t/d very conservative. A higher capacity would increase the economies

	Mass tailings [t]	Fe grade in tailings [%]	Fe grade in concentrate [%]	Mass Fe concentrate [t]	Metal value* [US$]	Costs of recovery [US$]
Magnetic separation	2.000.000	22	60	600.000	39.000.000	20.725.000

- For rion ore, transport costs are an important factor
- The calculation is based on a transport distance of 160 mile (to Caldera) and on costs of 0,10 US$/t/mile

*Precios: Fe 65 US$/t, Cu 5.500 US$/t

Processing tests to recover copper from the solution

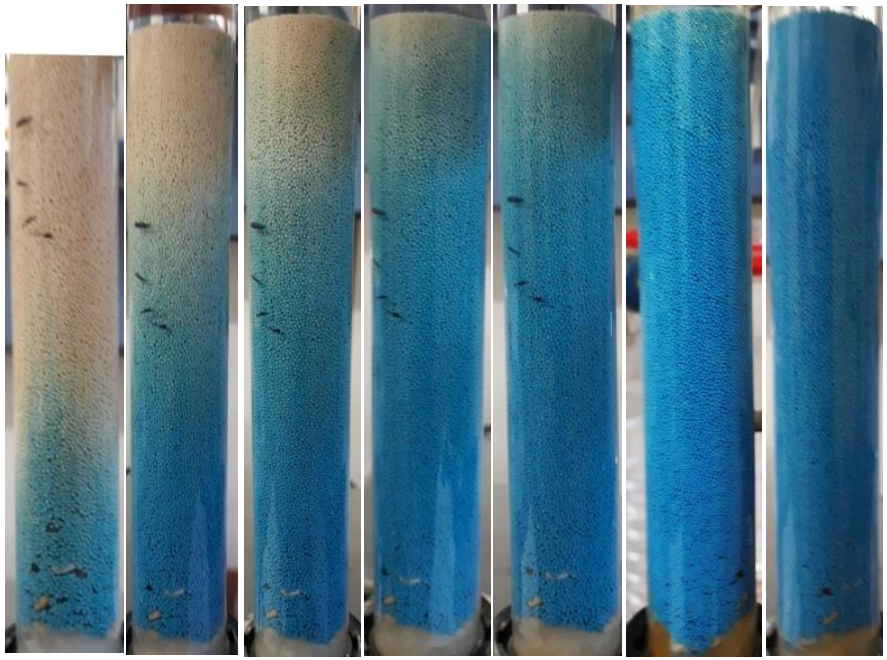
solvent-extraction

Re-extraction of copper from leaching solution:

- Due to low Cu grade in the leaching solution of only 700 mg/l, sovent extraction did not lead to sufficient Cu grades in the solvent medium
- To execute solvent extraction with subsequent electrowinning:
  - Elevate Cu grade in the solution by recirculating the solution, and/or
  - Apply a higher solid-liquid ratio

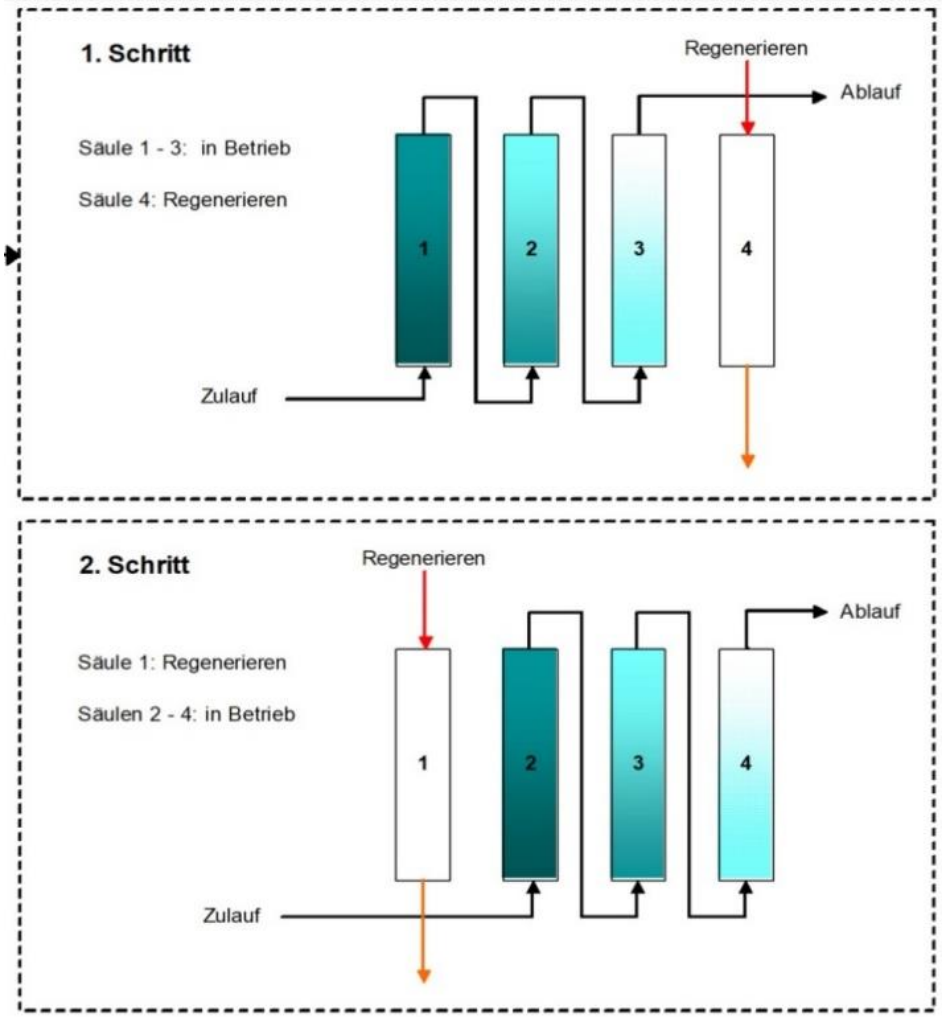
Ion Exchange

- Ion-Exchange works very effectively and almost the complete Cu is deposited on the resin



time [h]	0,75	3,0	3,5	5,25	6,25	12,5	24,25
Cu grade [g Cu/L resin]	2,0	8,5	11,6	16,9	19,7	33,5	47,6

Intercambio de lónos



Flow diagram and economies of the Ion Exchange process

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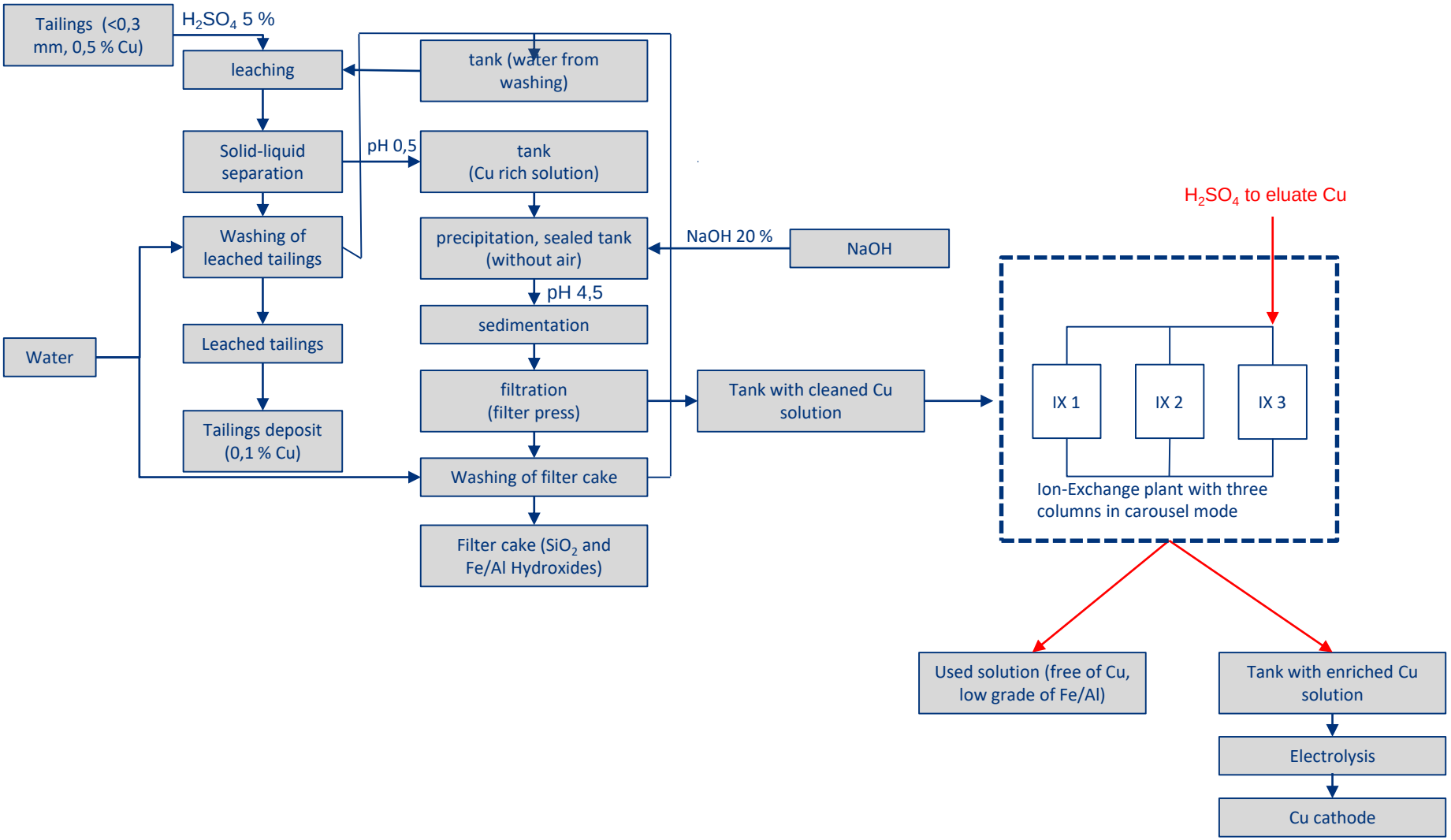

Economies of the Ion Exchange process

Economies:

Daily processing [t/d]	**500**	
Cu grade [%]	0,5	
Cu content in 500 t [t/d]	2,5	
Cu recovery		
Leaching recovery	80%	
IX EW recovery	90%	(losses during Fe-Al-SiO_2 sedimentation)
Total recovery	**72%**	
Annually recovered Cu [t Cu/a]	**525,6**	(20 % downtime repair, maintanance, malfunction, etc.)
Cu price [US$/t]	5.500	(variación 5.200 – 6.000 $/t)
Annual revenue [US$/a]	2.890.800	

Economies of the Ion Exchange process

Economies:

Cost estimation	
Investment	
Equipment	**2.000.000**
Infrastructure, planing and construction	**3.429.350**
Total investment	**5.429.350**
Annual processing costs	**870.055**
Total costs per year	
Depreciation over 10 years	**542.935**
Annual processing costs	**870.055**
Excavation and transport [3 US$/t]*	**438.000**
Total costs per year	**1.850.990**
Annual revenue	**2.890.800**
Annual profit**	**1.039.810**

* 500 t/d x 365 d x 80 % x 3 US$/t

** Faltan los costos de la redeposición de los relaves

Results

- As for primary deposits, only very few targets will become an economic reserve
- For an economic evaluation, the investment, the operating costs and the revenue of the sold products have to be estimated. Additionally, the costs for the final deposition also have to be considered.
- High variation of processing costs per tonne between projects with 100 Mio. t of tailings or more and small project of several Mio. t.
- Due to the low grades and the fact that the material has already been processed, recoveries will be relatively low, especially for flotation
- Recovery of pyrite can be quite good and lead to a far lower acid producing potential
- Sulfide flotation of tailings would result in a small mass of material with a high environmental hazard, but also to a very low environmental hazard for the bulk of the tailings

Finally

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