Mineral processing techniques for eco-efficient utilization of mining wastes

Examples from the KaiHaMe project

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Geological Survey of Finland

12.10.2017

Mining Waste Management Methods

FQM Kevitsa Mining

NEW BOLIDEN Kevitsa

Endomines

GTK gtk.fi

Centre for Economic Development, Transport and the Environment

kemira

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Mineral processing and materials research at GTK

- Outokumpu
  - Process mineralogy
  - Mineral processing at bench and pilot scale
- Espoo
  - Mineralogy
  - Isotope geology and trace elements

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Objectives in the KaiHaMe project (WP3)

- To reduce harmful components such as arsenic and sulfides in gold ore tailings
  - → Smaller volume of disposed hazardous waste
  - → More usable material, e.g., for earth construction at mine site
- To increase recovery of valuables such as gold and copper of excavated ores
  - → More economic mining process
  - → Smaller amount of disposed tailings
  - → Tailings less harmful for the environment

→ **More eco-efficient process**

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Kopsa gold deposit

- Porphyric Au-Cu-(Ag) deposit in Western Finland
- 13.6 Mt of ore with 0.81 g/t Au, 0.15% Cu and 2.15 g/t Ag
- Main sulfide/ore minerals: arsenopyrite, chalcopyrite, pyrrhotite and löllingite
- Mineralization contains elevated As (0.1–0.2%)
- Mining operations were under planning by Belvedere Mining Oy but the company went bankrupt in 2015

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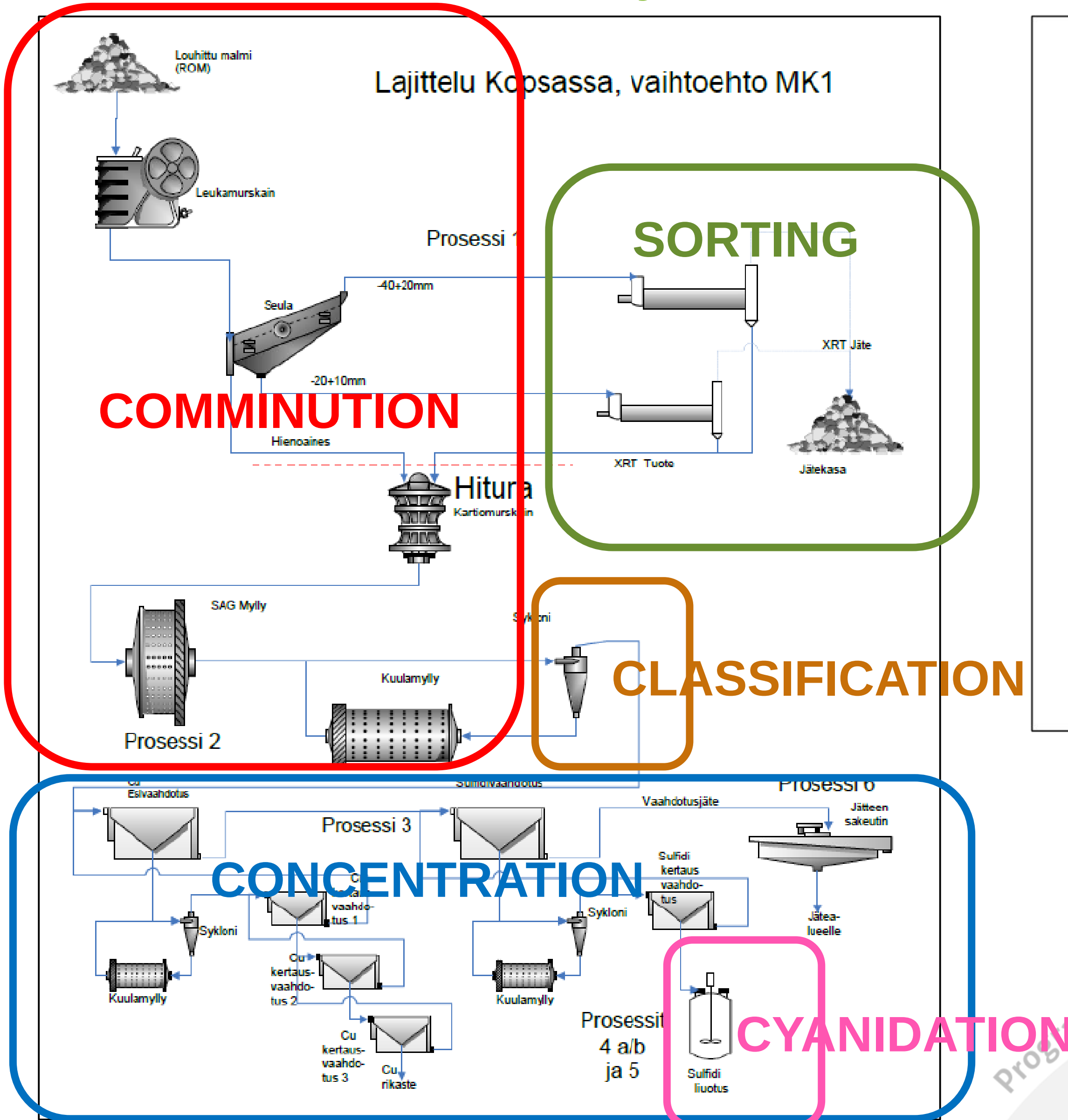
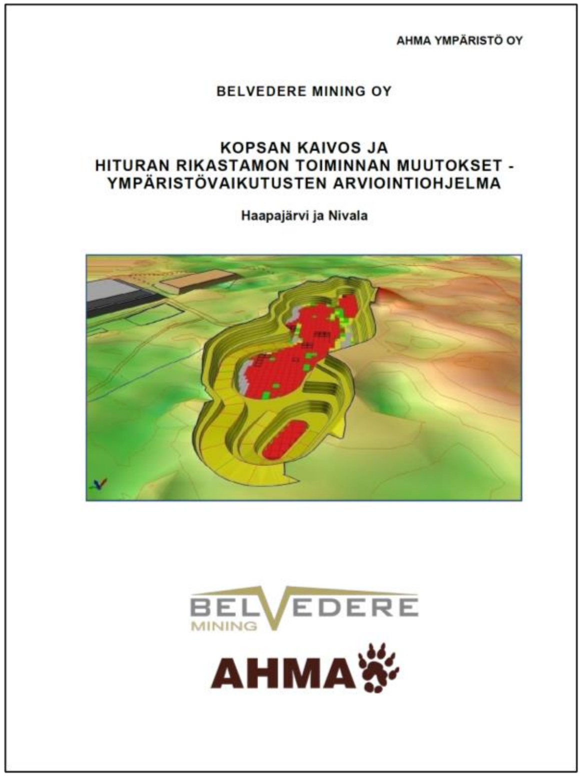
Process flowsheet by Belvedere





AHMA YMPÄRISTÖ OY

BELVEDERE MINING OY

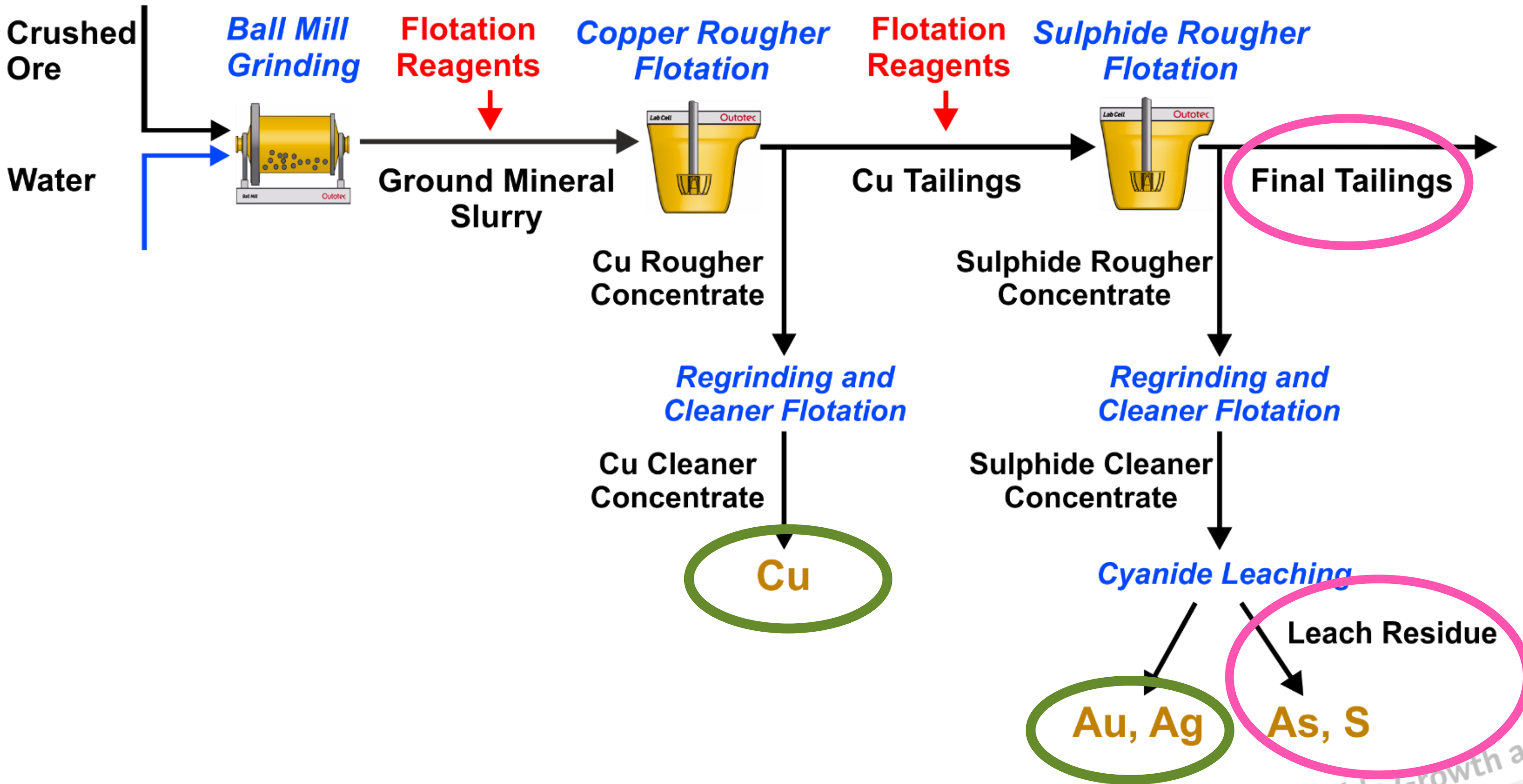
KOPSAN KAIVOS JA
HITURAN RIKASTAMON TOIMINNAN MUUTOKSET -
YMPÄRISTÖVAIKUTUSTEN ARVIOINTIOHJELMA

Haapajärvi ja Nivala

BELVEDERE MINING

AHMA

Simplified flowsheet for beneficiation



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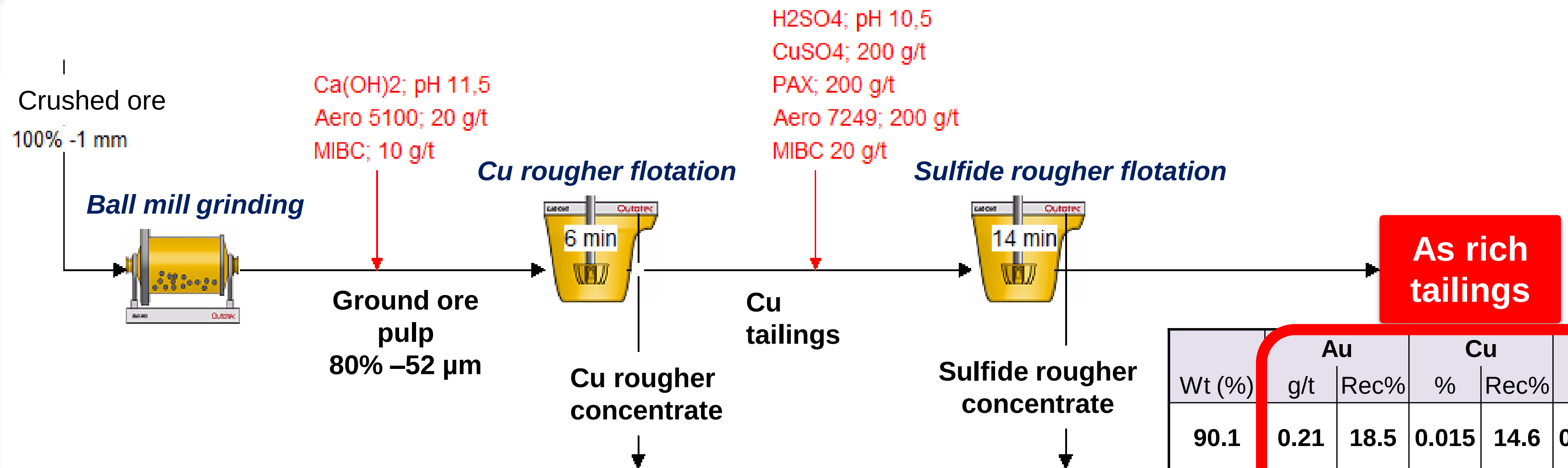
Beneficiation test following the original flowsheet (sorted ore)



Cu rougher concentrate

	Au		Cu		As	
Wt (%)	g/t	Rec%	%	Rec%	%	Rec%
2.2	13.0	28.0	2.7	63.5	7.7	27.2

Sulfide rougher concentrate

	Au		Cu		As	
Wt (%)	g/t	Rec%	%	Rec%	%	Rec%
7.7	7.1	53.5	0.27	22.0	5.6	69.2

As rich tailings

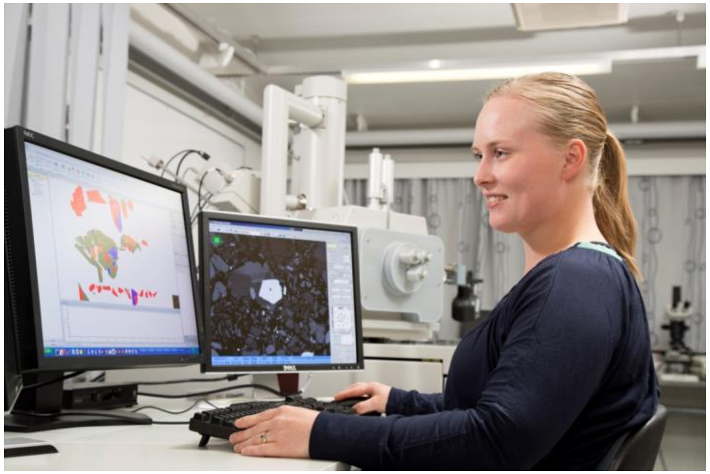
	Au		Cu		As	
Wt (%)	g/t	Rec%	%	Rec%	%	Rec%
90.1	0.21	18.5	0.015	14.6	0.025	3.6

S: 0.064%, Rec 8.8%

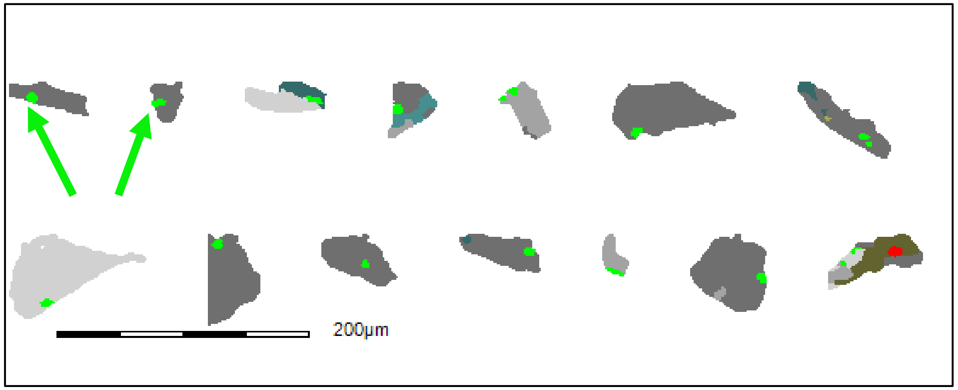
How to decrease concentration of valuables (gold, copper) and harmful elements (arsenic, sulfur etc.) in the tailings?

Detailed process mineralogical data is a prerequisite for rational planning a more eco-efficient process

- Minerals and their amounts
- Trace elements in minerals
- Grain sizes of various minerals
- Etc.



Ex. Chalcopyrite in +45 µm particles of the tailings



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Example: As mineralogy in Kopsa ore and tailings

Sorted ore

Mineral	-20 µm (%)	20-45 µm (%)	+45 µm (%)	All sizes (%)
Silicates	95.4	96.2	97.0	96.0
Arsenopyrite	1.76	1.81	1.33	1.71
Arsenate	0.06	0.03	0.01	0.04
Löllingite	0.00	0.03	0.00	0.01
Other sulfides	1.25	0.87	0.78	1.01
Gold				1.0 g/t

As rich tailings

Mineral	-20 µm (%)	20-45 µm (%)	+45 µm (%)	All sizes
Silicates	98.4	99.1	99.1	98.8
Arsenopyrite	0.04	0.00	0.00	0.02
Arsenate	0.04	0.02	0.01	0.02
Löllingite	n.d.	n.d.	n.d.	n.d.
Other sulfides	0.15	0.05	0.08	0.09
Gold	0.09 g/t	0.22 g/t	0.28 g/t	0.18 g/t

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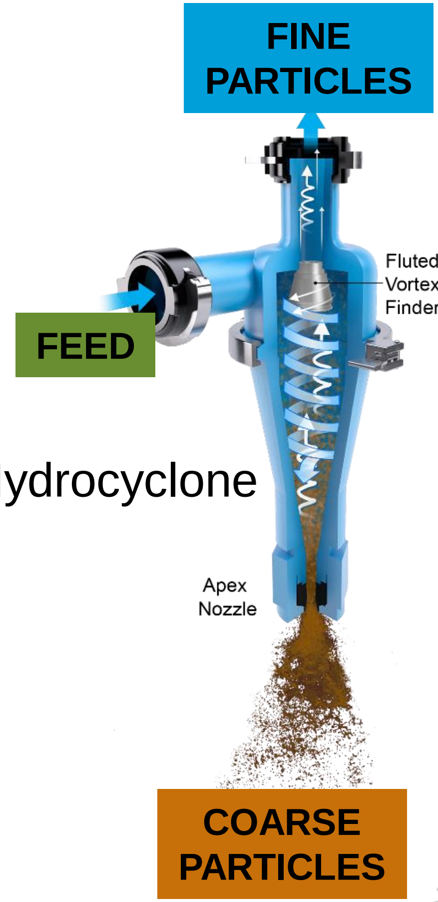
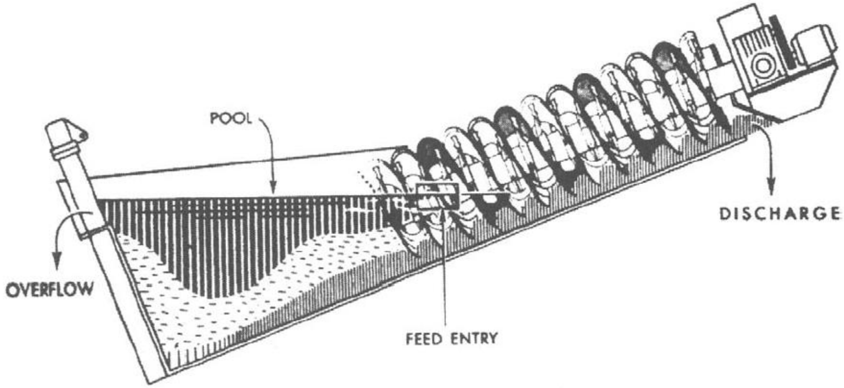
Classification/sizing

- Separation of particles by size
- Can be used as a way to separate harmful elements from tailings if they are distributed unevenly in various particle sizes



Hydrocyclone



Spiral classifier

Example: Classification of Kopsa As rich tailings

- Separation of fine particles (slime) from As rich tailings

	As rich tailings
Cu (%)	0,014
As (%)	0,030
S (%)	0,053

Laminar decantation →

	–15 µm	15–25 µm	+25 µm
Cu (%)	0,017	0,009	0,014
As (%)	0,068	0,013	0,016
S (%)	0,062	0,027	0,047

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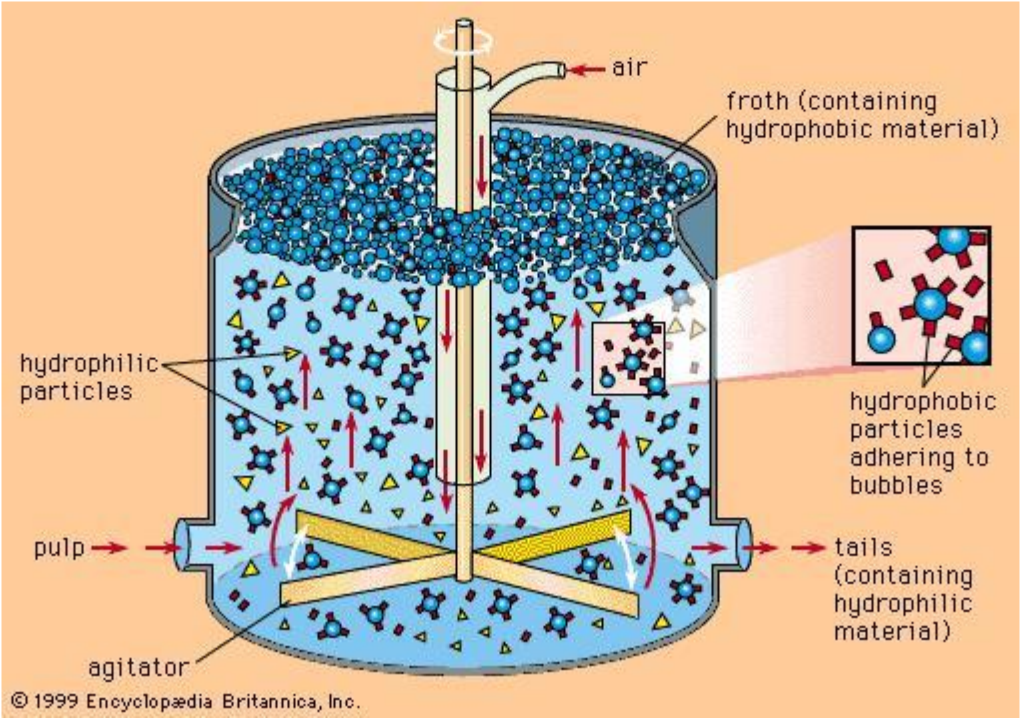
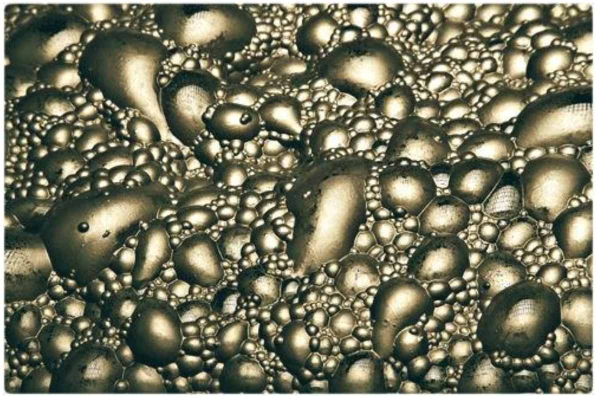
Froth flotation

- The most versatile method to separate mineral particles from each other
- Based on hydrophobicity differences between minerals. The differences are increased by using chemicals.

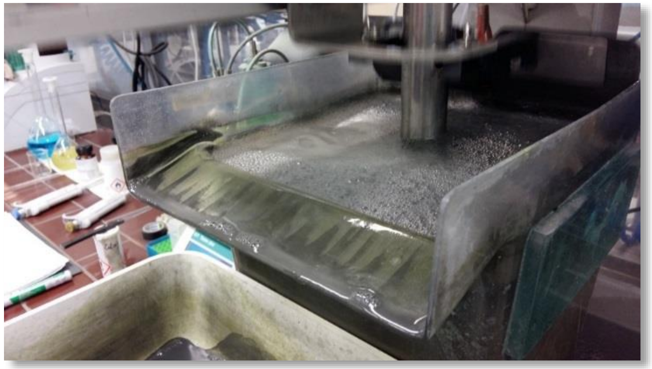




Example: Regrinding and flotation of tailings

	Tailings (P_{80} ≈ 44 µm)
Cu (%)	0,011
As (%)	0,020
S (%)	0,037

Regrinding
Chemicals
Flotation

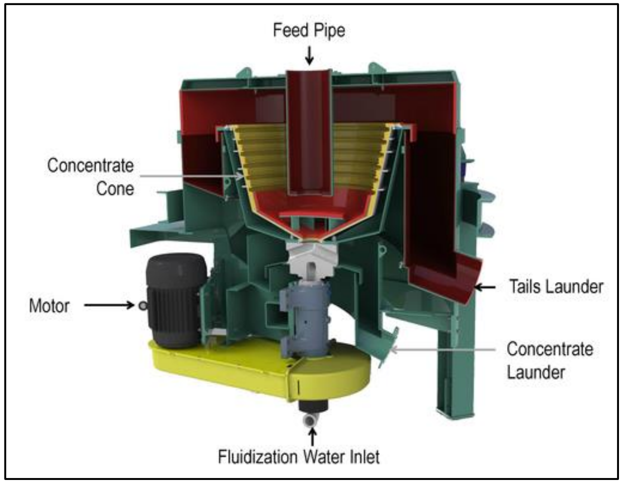


	Tailings (P_{80} ≈ 28 µm)
Cu (%)	0,010
As (%)	0,010
S (%)	0,023

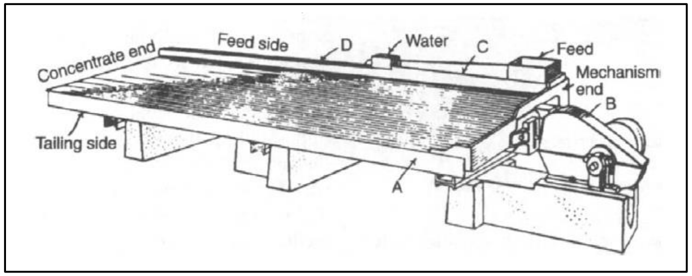
Gravity separation

- Increasingly used to recover heavy minerals in flotation tailings
- Based on specific gravity differences between minerals
- Relatively simple and cheap techniques
- Centrifugal concentrators can also treat very small particles (~10 µm)

Spiral



Knelson concentrator



Shaking table

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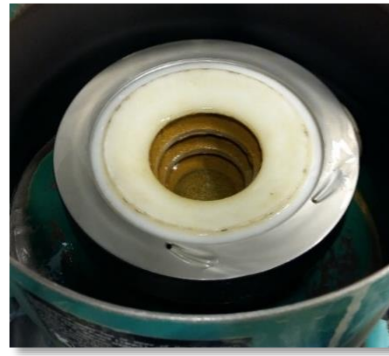
Example: Knelson concentration of As rich tailings

3'' Knelson concentrator
at GTK Mintec



	Concentrate	Tailings
Mass (%)	2.5	97.5
Au (g/t)	7.47	0.24
Cu (%)	0.025	0.015
As (%)	0.086	0.019
S (%)	0.126	0.053

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Magnetic separation

- Exploits the difference in magnetic properties between minerals
- Low-intensity separators used to concentrate ferromagnetic minerals (magnetite) mainly
- High-intensity and high gradient magnetic separators used to separate weakly paramagnetic minerals (e.g., rare earth minerals)

Wet low-intensity magnetic drum separator at GTK Mintec

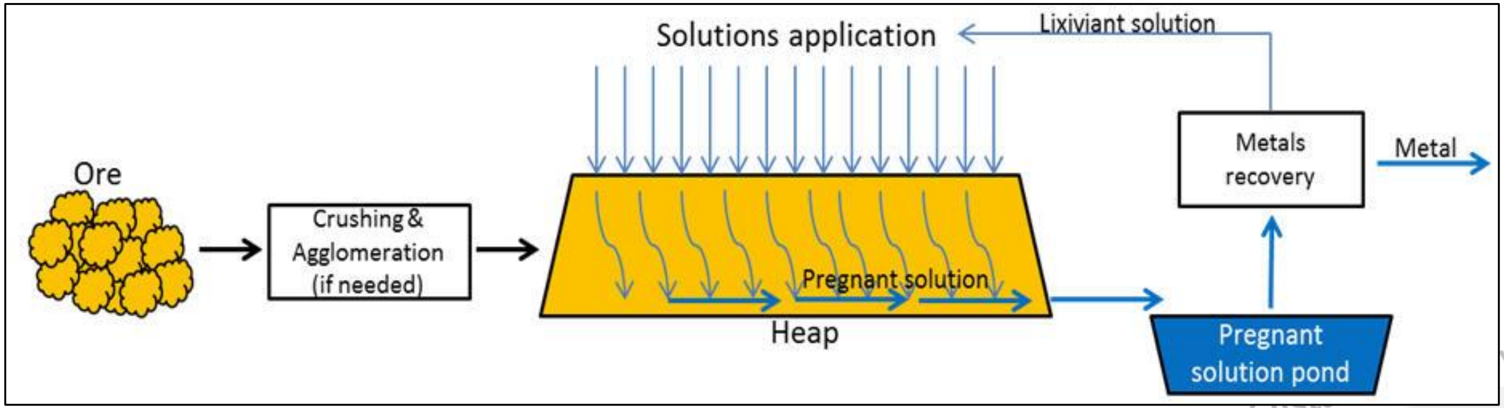
Example: HGMS separation of flotation tailings

High gradient magnetic separator (HGMS) at GTK Mintec

B = 1 tesla	Feed	Mags	Non-mags
Mass (%)	100	45.6	54.4
Cu (%)	0.010	0.017	0.005
As (%)	0.011	0.018	0.005
S (%)	0.019	0.032	0.008
Fe (%)	2.33	4.72	0.33

Hydrometallurgical methods

- Operationally quite uncomplicated and robust
- Frequently the most preferred option for re-treatment of tailings
- Heap leaching, tank leaching, bioleaching,…
- After leaching, the metal ions are recovered from the leach liqour
  - Precipitation, cementation, solvent extraction, electrowinning,…



Conclusions

- There are several mineral processing techniques that may be suitable for re-treatment of tailings
- Regrinding followed by flotation and HGMS seems one of the best options to decrease harmful components in the Kopsa tailings and increase its raw material value
- Economy of reprocessing needs to be evaluated with respect to acquired benefits in the waste management


Thank you for your attention!
Contact: antti.taskinen@gtk.fi
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