Some examples of reuse, repurposing and recycling of minerals to improve the resource efficiency in mining

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The World Federation of Engineering Organization's (WFEO)

- Committee of Engineering and the Environment

- Task Group of Mining and Sustainable Development,
  Task Force Chair: Nikhil Trivedi.

- **Engineering solutions to reuse, repurposing and recycling of minerals**

• Burhan Sahin	Turkey
• Chris Moran	Australia
• David Laurence	Australia
• Dirk Van Zyl	Canada
• Ilkka V. Kojo	Finland
• Mutale Chanda	Zambia
• Zach Agioutantis	Greece
• Zhongxue Li	China
• Bouke Martijn van 't Riet	Finland

Recycling, Reusing, Repurposing

- “I am a miner and this is what I think of recycling….. “

- On the other hand
- We can do it

Sustainable Development - Brundtland

3. Sustainable Development

27. Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs. The concept of sustainable development does imply limits - not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities. But technology and social organization can be both managed and improved to make way for a new era of economic growth. The Commission believes that

Sustainability

Resource Efficiency

…from original Brundtland document.

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technology

improved

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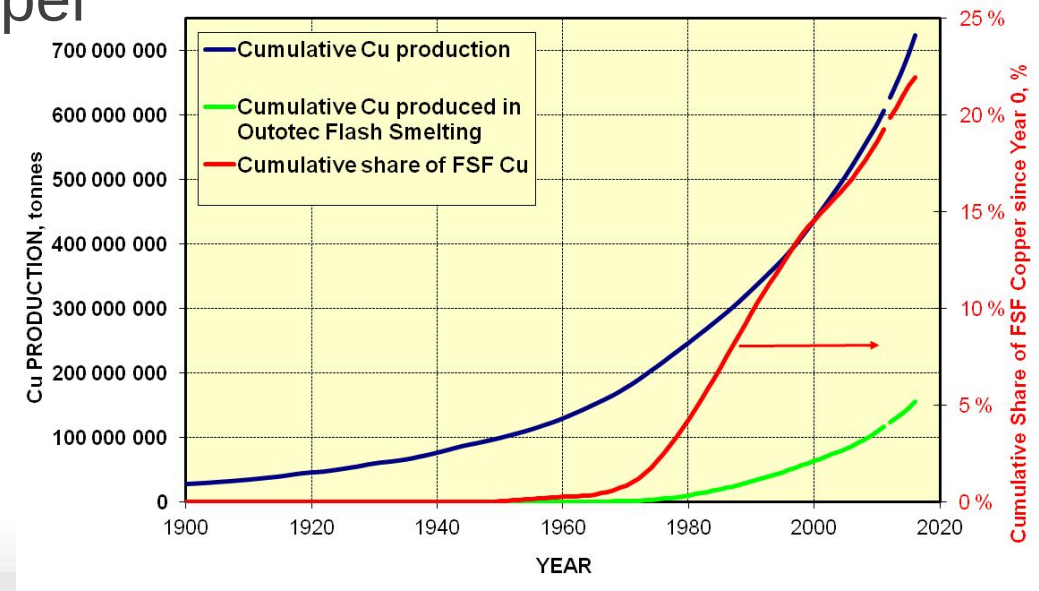
Reuse, Repurposing and Recycling of Minerals

- The recyclability of metals makes it possible for future generations to use the same metals that have already been used, therefore providing a service to our descendants by mining the ore and refining it to metal.
- China is already targeting to circular economy

- There are also good examples how metal ore and processing residues can be utilized by using more efficient technologies
- Doing more with less: It is all about **Resource Efficiency**

POTENTIAL FOR SECONDARY MINING, example

- More than 95% of the copper ever produced has been mined during the last 200 years.
  - Order of magnitude is about 600 million tonnes metallic copper
  - The potential for secondary mining is in order of 150 million tonnes of copper

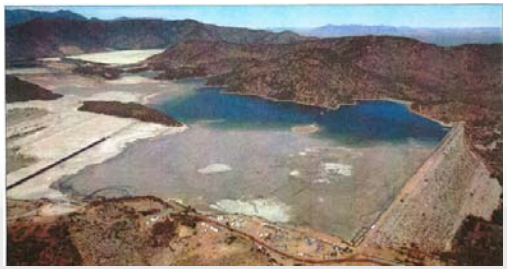


EXAMPLE CASES

- El Teniente tailings, copper
- *Timmins, Canada, gold*
- *Kemira, Finland repurpose iron sulfate residue*
- *Nordkalk, Finland, commercialization of filter sand*
- Keretti Mine, Finland, cobalt, pyrite
- Kongo slag residues, cobalt
- Cobalt recovery from pyrite calcine Imatra, Finland (1936-1947)

El Teniente tailings, copper

- Codelco's El Teniente copper mine near Rancagua in Chile has been operated for decades and it has a large tailings pond called Colihues
- Codelco sold rights to "re-mine" the tailings ponds Mineral Valle Central in 1990 to extract copper and molybdenum from those tailings.
- Now operated by Americo Resources.
- In 2012 Americo produced 51.7 million lb copper (23 450 tons) and 1.06 million lb of molybdenum (481 tons) from El Teniente tailings



Reference: The Northern Miner, (2013). March 4-10, pp. 18-19.

Timmins, Canada, gold

- In Timmins, Canada, there were old sulphide gold mine tailings from the 1920s.
- Australian ERG Resources tried to utilize these resources and recover leftover gold in the sand.
- The residues were mined by means of high pressure water cannons and the obtained already fine grained material was regrind in a small ball mill.
- Followed by grinding the material was taken into flotation, where gold containing concentrate was produced.
- Principally the technology worked, but perhaps due to the local environment and low temperature the concentrator was only able to operate 8 months a year and finally the reprocessing of concentrate sand became uneconomic.

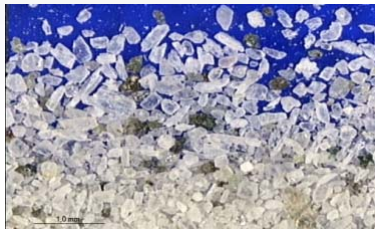
Reference:
http://www.timminstimes.com/2012/10/12/timmins-citizens-grill-goldcorp-over-plans-for-hollinger-open-pit-mine.

Kemira, Finland repurpose iron sulfate residue

- Kemira Oyj produced TiO_2 pigments at its plant in Pori, Finland (today operated by Sachtleben)
- The process involved leaching of iron from the ore with sulfuric acid.
- Iron was then crystallized as iron sulfate from the solution and filtered off.
- End of 80's there were no use for large amounts of iron sulfate and during the early days of operation the iron sulfate was pumped into the sea.
- However, this was not considered sustainable and Kemira started to stockpile both iron sulfate and gypsum, fortunately in separate stockpiles.
- A bit later Kemira invented, that iron sulfate can be used as a precipitation reagent in water purification and they started to recycle the iron sulfate residues as raw material in water purification reagent production.
- The old tailings were repurposed to a new business application
- Today Kemira's main business is in water treatment chemicals

Reference: Kemira Oyj, (2003), Annual Report.

Nordkalk, Finland, commercialization of filter sand



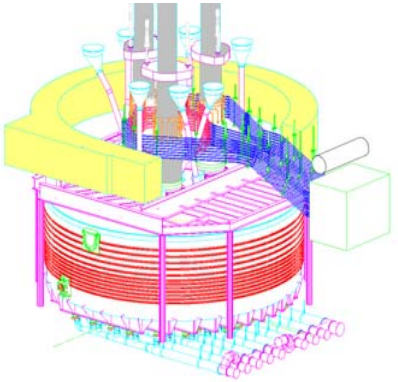
- Nordkalk Corporation extracts and processes limestone for industry, agriculture and environmental care.
- Flotation is used to separate calcite from limestone
- Filter sand is produced as a side product in the extraction process.
- Since the 1960's a part of this filter sand has been used as a part of mixture of a lime fertilizer.
- The products Nordkalk Aito Calcite Lappeenranta and Nordkalk Aito Magnesium Lappeenranta have official certificate to be used in organic agriculture from Finnish Food Agency.
- The company has also commercialized the filter sand to be used in earth and environmental construction.
- This is a good example of resource efficiency and repurposing of mineral material

Reference: Vallius, Pekka. Nordkalk FS suodatinhiekan tuotteistus. GeoPex Oy, Finland, (2008).

Kongo slag residues, cobalt

- In Lumumbashi (DRC) there has been copper production including smelting for more than 100 years.
- Slag left from the copper smelting operations was been stockpiled (height 120 meters, diameter 150 meters, about 14 million tons) containing copper, but especially large amounts of cobalt, 2.5 % Co.
- OMG group obtained the rights to utilize these slags in 1997 and build a modern slag reduction smelter based on Outokumpu Technology's (today Outotec) process knowhow and proprietary equipment including the electrical furnace, gas treatment and granulation of the Cu-Co-containing iron based bottom metal
- The bottom metal is then transported to Kokkola, Finland, where the cobalt is further recovered.
- The cobalt and copper is recovered from the leaching solution by using Outotec's solvent extraction and electro winning processes (SX-EW).
- The plants are still in operation today by Freeport-McMoran Gold and Copper

Slag pile in Lumumbashi



Modern electric furnace

Reference: Vuoriteollisuus-Berghanteringen, OMG isolla apajalla, (2000), pp.20-21.

Keretti Mine, Finland, cobalt, pyrite

- During 1970's Outokumpu started to explore the old Keretti mine Mökkivaara tailings area by sampling and they found areas where the tailings were still rich in cobalt and pyrite.
- The "re-mining" was carried out mechanically followed by regrinding in a small ball mill in order to reactivate the sulphide containing surface areas of the tailing.
- Flotation was carried out by using (at that time) the latest development of Outokumpu , today Outotec) flotation technology.
- Cobalt or pyrite concentrates were further processed in Kokkola, Finland, which started cobalt production in 1968.
- Later the operation of the whole mine was fading and today the old Mökkivaara tailings area is remediated and serves as golf resort

Latest Outotec flotation cell

Outokumpu Golf

Reference: Tarvainen, M., Outotec, (2013). Personal communication.

Cobalt recovery from pyrite calcine
Imatra, Finland (1936-1947)

- Cobolt was recovered in Imatra 1936-1947 from pyrite calcine
- Pyrite (from Outokumpu mine) was first roasted to recover SO_2 to acid production else where (to be used in pulp and paper industry) and transported to Imatra, where the process involved
  - Chlorinating roasting (convert Cu, Au, Ag, Co, Ni, Zn into soluble compounds)
  - Leaching of soluble compounds and their multi step recovery
  - ”Purple ore” (hematite) to pig iron production

Reference: Palperi, M., Miten Imatralla tehtiin kobolttia vuosina 1936-1947. Materia #3 (2010), pp.27-32.

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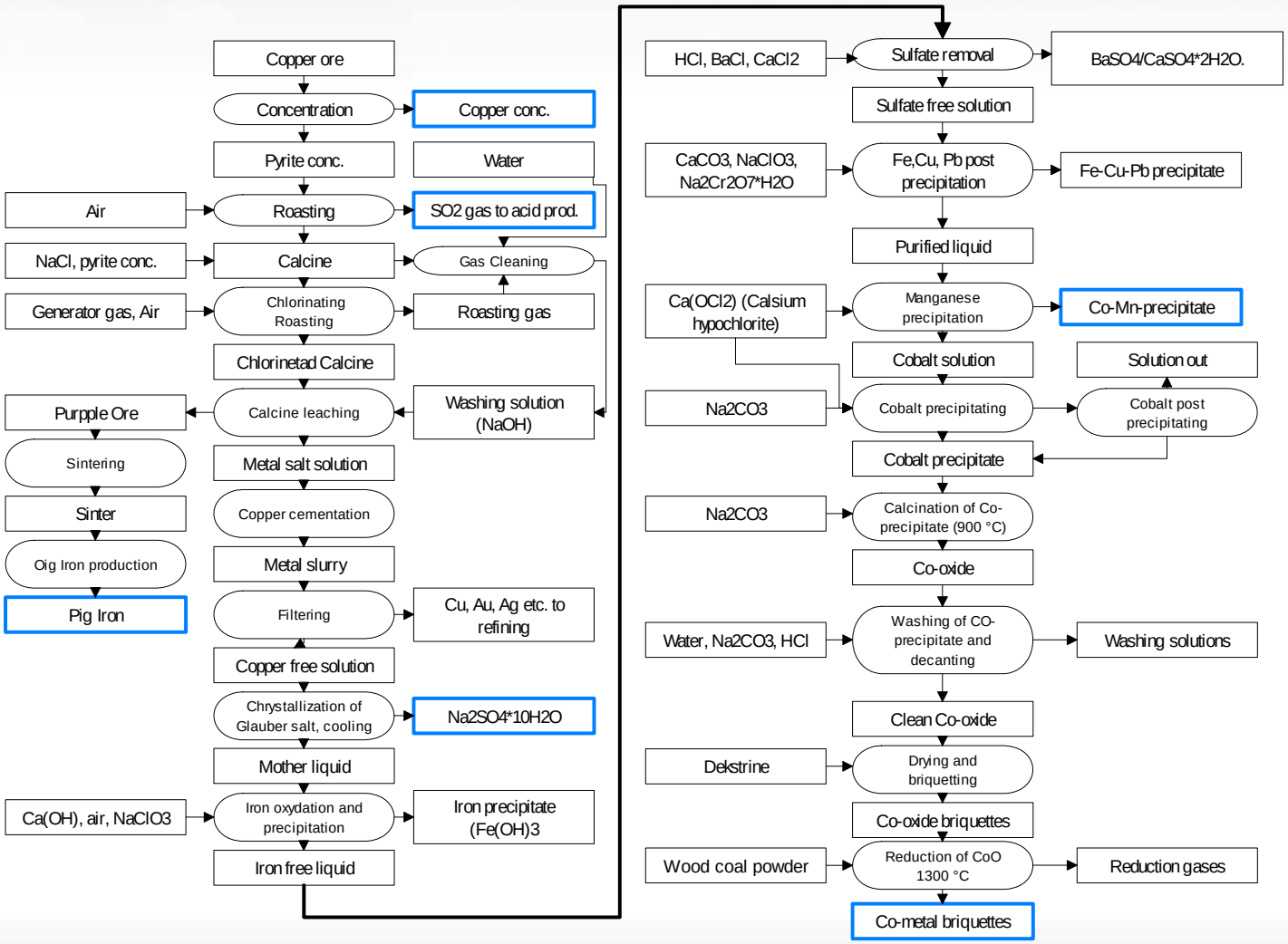
Amazing Imatra Process Flowsheet



Reference: Palperi, M., Miten Imatralla tehtiin kobolttia vuosina 1936-1947. Materia #3 (2010), pp.27-32.

CONCLUSIONS

- There are lot of business opportunities in reuse, repurposing and recycling of mineral residues rising from the minerals and metals production
- To be able to utilize these resources new engineering solutions are already available, but there is still potential to improve our technologies, world is not yet ready
- The cases are also evidence that sustainability of mining operations can be increased by increasing the total resource efficiency (by using new technologies) in an economically profitable way
- The task force wishes to have your input in the collecting good examples of repurposing , reuse and recycling of mineral materials

Sustainable use of Earth’s natural resources

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Thank you for your attention!

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