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

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ABSTRACT

The metals in the earth's crust have clustered in certain locations in much higher concentrations than average due to geothermal processes. This great eco-service provided by nature has made it possible for society to produce metals. The same applies for industrial minerals. However, mining of metals generates large amounts of side stream materials, which today are not fully utilized. For example to produce 1 tonne of copper requires about 125 more tonnes of ore to be milled, which also results in an increased amount of tailings and the consumption of energy and water. This has given mining a "non-resource efficiency activity" reputation. However, resource efficiency has the aim also to utilize these resources, which have been once mined from the earth.

The World Federation of Engineering Organization's (WFEO) Committee of Engineering and the Environment started in 2012 a Task Group of Mining and Sustainable Development. One of the thematic areas is "Engineering solutions to reuse, repurposing and recycling of minerals". The aim of this task group is not to make much scientific ways to improve resource efficiency, but to find examples of existing solutions, which enable improved total resource efficiency in mining and which should show the way to future.

The paper presents some examples of improved resource efficiency in mining and metals extraction.

1. INTRODUCTION

The Brundtland definition for sustainability is: "*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*". Recyclability of metals makes it possible to say, that metals mining can be sustainable. To put it simply: 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. The Brundtland report also discusses ***"Industry: Producing More With Less"***, which is at the heart of recycling (UNEP, 2013). This key theme was taken up by the World Business Council on Sustainability Development as "Doing more with less". Resource efficiency can be improved significantly by re-cycling but also through the reuse and repurposing of non-renewable resources.

Resource efficiency thus also implies reducing the environmental impact of the consumption and production of goods and services over their full life cycle. The "Doing more with less" slogan indicates the focus on more outputs with fewer impacts.

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2. POTENTIAL FOR SECONDARY MINING

More than 95% of the copper ever produced has been mined during the last 200 years. An intelligent estimate of the total amount of copper produced during the last 200 years is about 600 Million tonnes metallic copper. In the past concentrator methods were not very advanced and the mining and concentrator operations from those days could be characterized to be "cherry picking". Thus there are residues from the concentrator plants, which still today contain significant amount of copper and other metals, which could still be recovered economically feasible way by using today's techniques. A careful estimate of the copper contained in the old concentrator concentrate sand (based on 80 % recovery of copper in concentrator) indicates the potential is in range of 150 million tons of copper. A few examples of those operations as well as some other ways to improve general resource efficiency in mining are given in the next section.

3. SOME EXAMPLES OF REUSE, REPURPOSING AND RECYCLING OF MINERALS

3.1 El Teniente tailings, copper

Chilean state owned copper producer Codelco has been operation its El Teniente copper mine near Rancagua in Chile for decades and it has a large tailings pond called Colihues. Mineral Valle Central was set up in 1990 to extract copper and molybdenum from those tailings. The operation was profitable for a few years, but because the copper price fell in 1997 the profitability was lost. An experienced mining person, Klaus Zeitler invested in MVC in 2003, because he was convinced that the copper price would go up. And soon after that it really happened. Nowadays the tailings are operated by Americo Resources in which the MVC was injected. 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. About 50% of the production comes from fresh tailings. As there was no investment needed to the construction of the mine itself and that the material was already mined, the capital cost of the production is negligible and also the operation costs are very low. The technology needed for remaining is using high pressure water sprays to release the old tailings. Thus the production is extremely profitable (The Northern Miner, 2013).

3.2 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 and by early 1990s, the company ran out of money and stopped operations (Timminstimes, 2012).

3.3 Keretti Mine, Finland, cobalt, pyrite

A good example of utilizing old mining residues has been documented for old Keretti Mine in Finland. The operation of the mine, which was the richest copper ore body in Europe, was started early 1900's. During 1970's Outokumpu started to explore the old Mökkivaara tailings area by sampling and they found areas where the tailings were still rich in cobalt and pyrite. Outokumpu started the reprocessing of the tailings to recover, depending on the price, either cobalt or pyrite concentrates to be further processed in Kokkola, Finland. The mining was carried out mechanically followed by regrinding in a small ball mill. This was necessary to reactivate the sulphide containing surface areas of the tailing. Then the old tailings were flotated by using (at that time) the latest development of Outokumpu (today Outotec) flotation technology. Later the operation of the whole mine was fading and today the old Mökkivaara tailings area is remediated and serves as golf resort (Tarvainen, 2013), (Fig. 1).

Figure 1: A view of Outokumpu Golf on the old Keretti Mine area today (Outokummun Golfseura ry, 2013).

3.4 Kongo slag residues, cobalt

In Lumumbashi (DRC) there has been copper production including smelting for more than 100 years. During these years the slag left from the copper smelting operations was been stockpiled so that the pile was estimated to be about 120 meters high and 150 meters in diameter and containing about 14 million tons of material containing copper, but especially large amounts of cobalt, 2.5 % Co. This could not be recovered at the Lumumbashi old copper smelter.

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, which was formed in the furnace due to reducing conditions. The bottom metal was then transported to Kokkola, Finland, where the cobalt is further recovered. The copper in the bottom metal 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, although just recently OMG sold the Kokkola assets to Freeport-Macmoran Gold and Copper, which is continuing the operations of the biggest cobalt plant in Europe (Vuoriteollisuus, 2000).

3.5 Kemira, Finland repurpose iron sulfate residue

Kemira Oyj, a Finnish company, which today is a global water chemistry company serving customers in water-intensive industries, used to produce TiO_2 pigments at its plant in Pori, Finland. 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. The other residue of the process was gypsum. 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 low manganese containing 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. Thus the old tailings were repurposed to a new business application (Kemira Oyj, 2003).

3.6 Nordkalk, Finland, commercialization of filter sand

Nordkalk Corporation extracts and processes limestone for industry, agriculture and environmental care. In the Lappeenranta unit in Finland a flotation process is in use: the limestone is first ground into a wet slurry and the concentrated calcite is separated from the slurry by flotation. 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. Thus this is a good example of resource efficiency and repurposing of mineral material (Nordkalk, 2008).

4. CONCLUSIONS

Large amounts of waste rock and tailings are produced in mining operations. Often the utilization of these materials as products is limited by the economics. Also the environmental criteria for by products may be limiting the use of these materials.

The examples given in the text above show, that there are lot of business opportunities in reuse, repurposing and recycling of mineral residues rising from the minerals and metals production chains. They is also evidence that sustainability of mining operations can be increased by increasing the total resource efficiency in an economically profitable way.

There are many of this type of re-mined materials available in old mine areas and most of them need some new technologies to recover the metals by an economically acceptable way. World Federation of Engineering Organization's (WFEO) Committee of Engineering and the Environments "Task Group of Mining and Sustainable Development" thematic areas "Engineering solutions to reuse, repurposing and recycling of minerals" group wishes to encourage mining and metallurgical producers to rethink and try to find engineering solutions, and how to utilize the wastes of today in an more resource efficient way.

The task group still continues its work and all new examples of are welcomed with warm thanks!

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REFERENCES

Kemira Oyj, (2003), Annual Report.

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

Outokummun Golfseura ry, http://www.ogs.fi/

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

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

UNEP, (2013). Metal Recycling: Opportunities, Limits, Infrastructure, A Report of the Working Group on the Global Metal Flows to the International Resource Panel. Reuter, M. A.; Hudson, C.; van Schaik, A.; Heiskanen, K.; Meskers, C.; Hagelüken, C., 322p.

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

Vuoriteollisuus-Berghanteringen, #3, OMG isolla apajalla, (2000), pp.20-21.