# Beneficiation of Potassium Feldspar from the West Pilbara for processing to Potash Fertiliser

William Hynes

Hui Tong Chua
Chemical Engineering
The University of Western Australia

Alan Ooi
CEED Client: API Management Pty Ltd (APIM)

**Abstract**

*Global Potash markets, particularly those in Asia, are currently lacking in supply. Australian production, for domestic markets and export, via the traditional brine evaporation methods is currently stalling for unknown reasons. API owns mining tenements containing significant deposits of Potassium Feldspar which, in a novel process being studied for feasibility, may serve as a hard-rock feedstock to produce Sulphate of Potash (SOP) for domestic markets and export. In order for pyrolysis for Potassium Feldspar to SOP to occur, beneficiation upgrade of the feedstock must be performed. This research explores how a run-of-mine feed primarily containing Potassium Feldspar, Pyrite, Quartz and Bituminous Coal may be upgraded, preserving the Pyrite by-product stream for use in the pyrolytic processing stage being explored by CEED scholar Jiahao Zuo. High-level process plant design, pre-feasibility studies and economic analysis for equipment selection have been performed and are detailed below.*

## 1. Introduction

China's production of Potash has been reduced by approximately 20% and they represent the Asia-Pacific region's largest exporter of SOP, this region accounting for 45% (IndustryARC 2021) of the world's potash market. Owing to political pressures, Russia and Belarus are being sanctioned and their previous stake as the exporter of 41% of the world's potash has been impacted (Glauber & Laborde 2022). There are no current SOP producers in Australia and for these reasons, diminishing supply does not meet growing demand in Asia or globally (Kalium Lakes 2018). This gap in the market represents an opportunity for SOP, a premium product worth approximately 200% more than Muriate of Potash (MOP/KCl) (IndustryARC 2022), to be economically viable to produce.

Part of APIM's West Pilbara tenements contains a significant quantity of Potassium Feldspar deposits at surface, speculated by in-house geologists to have resulted from prehistoric volcanic activity. The potassium content of this easily mined, abundant mineral makes it a potentially attractive candidate for use as a feedstock for Potash fertiliser. The failure to achieve sufficient concentration of Potash from subterranean brine is, therefore, avoided, meaning this hard rock extraction process may be more reliable than traditional methods in Australia. This process has not been commercially developed before, so this research is primarily to study the feasibility of a potential process design.

## 1.1 Current practice

Beneficiation of Potassium Feldspar is typically performed using a combination of Dense Media Separation (DMS) and Flotation (Zhang et al. 2018). Owing to the large difference between the specific gravity of Potassium Feldspar and Pyrite, a DMS cyclone separation would be consistent with the current industrial practices (Tuckey et al. 2016). The less distinct specific gravities of Silica Quartz and Potassium Feldspar demand that separation of Silica be performed by flotation methods. Considering the distribution of gangue material throughout the ore (see Figure 1) a very fine particle size is required to achieve sufficient liberation of Potassium Feldspar.

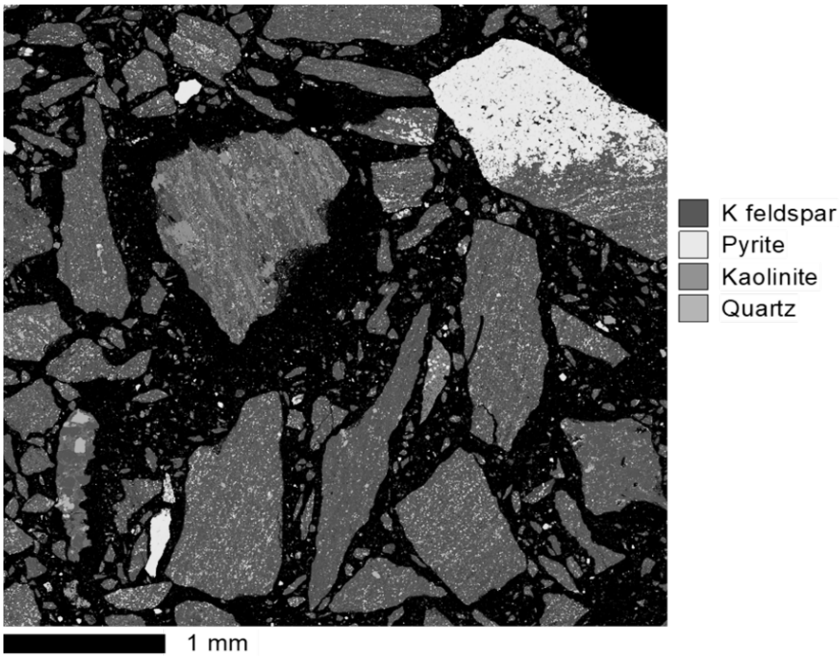


**Figure 1** Scanning Electron Microscope image of proposed Run Of Mine ore

Based on recommendations from Bureau Veritas' laboratory mineralogy report, a particle size of approximately 0.3mm or less would be most appropriate to achieve the required upgrade. The liberation of the concentrate minerals from gangue was shown by the Bureau Veritas data to be proportional to the degree of comminution, which in turn is related to increased energy consumption. An optimal point between low comminution energy/low liberation and high comminution energy/high liberation must be determined based on minimum liberation requirements for sufficient beneficiation and operational cost effectiveness.

Comminution to such a great degree must be optimised as this represents the biggest consumer of energy in this beneficiation process. High-Pressure Grinding Rolls (HPGR) provide a more energy efficient method of grinding than Ball/SAG Mill and is characterised by high and steady throughputs, lower Capex and Opex than traditional equipment of similar performance, reduced footprint and low dust and noise emissions (Klymowsky n.d.). For these reasons HPGR is being considered as an optimal method to grind the ore before the wet beneficiation stages.

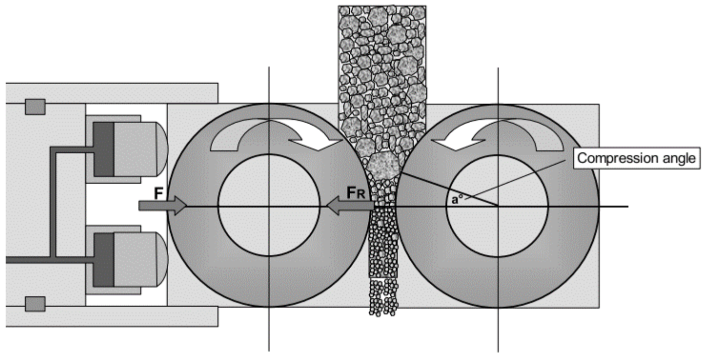


**Figure 2** HPGR Schematic (Retrieved from Klymowsky n.d.)

Traditional flotation methods don't perform optimally with particle sizes less than 0.5mm, as the large bubble size and low specific surface area adheres best to larger particles (Bulatovic 2007). Current processes in mineral beneficiation requiring flotation of fines typically employ the Jameson Cell. The Jameson Cell is more energy efficient than traditional flotation equipment as it uses entrainment to introduce bubbles in the "downcomer" rather than expending energy on slurry agitation and air compression. Consequently, the flotation bubbles are much finer, resulting in greater surface area and improved ability to adsorb fine hydrophobic particles (Harbort & Lawson 2003).

While beneficiation of Potassium Feldspar for other uses such as glassmaking is currently performed on similarly small scales to that being studied in this project, it is not yet employed for the purpose of Potash Fertiliser production. The pyrolytic processing (as studied by Jiahao Zuo in his corresponding CEED project) places specific demands on the performance of the upgrade of Potassium Feldspar, and also requires that Pyrite be preserved in a separate stream to be consumed downstream as a source of Sulphur for the secondary processing of Muriate of Potash (KCl) to the superior (Venkatesan et al. 2006) Sulphate of Potash ($K_2SO_4$).

# 2. Process

## 2.1 LIMN Flowsheet

In establishing the plausibility of upgrading Potassium Feldspar to a suitable grade for pyrolytic conversion to Potash Fertiliser, based on a high-level mineralogy report from Bureau Veritas Laboratory, a flowsheet was produced in LIMN to estimate the process route and parameters. Based on those results, lab scale tests were performed on samples from the orebody to verify the unit operations' performance. The flowsheet depicts the comminution and wet beneficiation processes. LIMN allowed the simulation to balance the four most significant mineral species Pyrite, Potassium Feldspar, Coal and Quartz, moisture, and to depict Particle Size Distributions in each stream, to match the performance in the lab testing results.

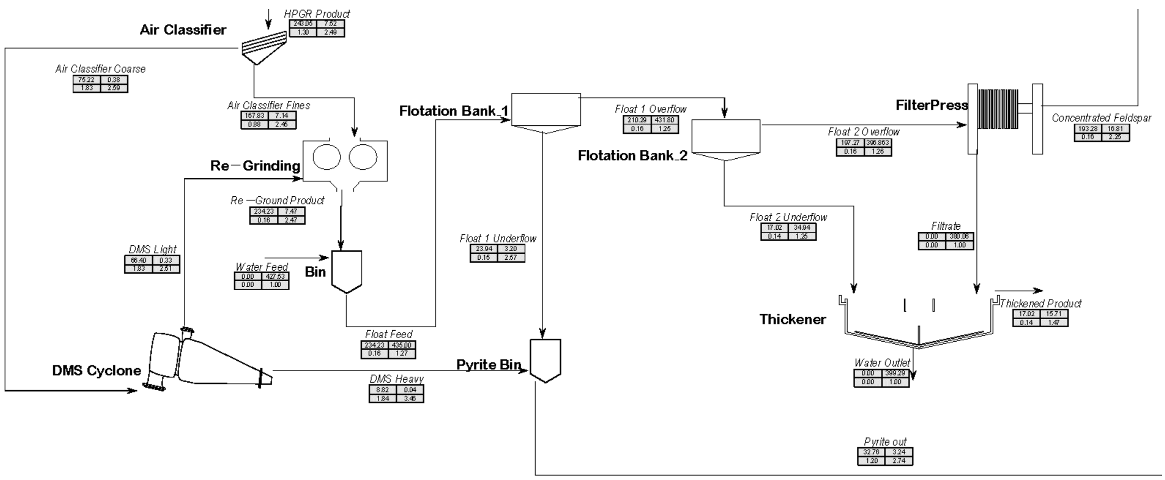


**Figure 3** LIMN Process Flow Sheet – Wet Beneficiation Stage

## 2.2 Bruno Comminution Flowsheet

The Comminution section of the flowsheet was refined by producing a detailed flowsheet in Metso-Outotec's Bruno software, which selects mineral processing equipment (crushers, screens, HPGR and air classifier) from Metso-Outotec's catalogue. Where LIMN uses a selection of theoretical models based on bond work index to determine degree of comminution, Bruno extrapolates performance from empirical data from the industry use of the specific Metso-Outotec equipment. This enables a more refined estimate of the PSDs and an informed and itemised breakdown of energy consumption per unit to help estimate Operational Expenditure and CO2-e emissions. Crushing Work Index for input to this simulation was derived from lab testing by Geopyora. Bruno was also used to trial different comminution parameters in order to optimise energy consumption, with final Particle Size Distributions used as a manual input to the overall LIMN flowsheet simulating the wet beneficiation stages.

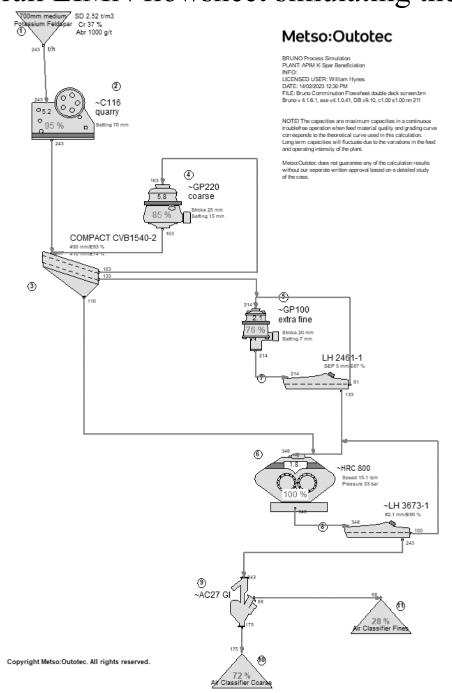


**Figure 4** Bruno comminution flow sheet

# 3. Results and Discussion

## 3.1 Financial Analysis

Based on high-level quotes from prospective suppliers, capital expenditure is predicted at around USD$450-500M for a plant producing 250ktpa of SOP.

Economic Analysis considering labour costs, reagents and calculated power costs indicates an operational expenditure per tonne of USD$387 and a current SOP price of USD$1030-1060/tonne which means that, assuming a capital expenditure of USD$400-450M and 250ktpa of production, the asset breaks even after approximately 2 ½ years. In addition, the price of SOP is expected to continue to grow throughout the rest of the decade (Data Bridge 2021) so this predicted time may be reduced.

Alumina as a by-product may provide additional revenue but would imply greater capex, further investigation is required.

Given USD$500 Million CAPEX, 250ktpa production, USD$387 per tonne OPEX, discount rate of 10% and market value of USD$1045 per tonne:

| End Year | Annual Cash Flow ($M) | Cumulative Cash Flow ($M) | NPV ($M) |
|---|---|---|---|
| 1 | 164.5 | 164 | -335 |
| 2 | 164.5 | 329 | -171 |
| 3 | 164.5 | 493 | -6 |
| 4 | 164.5 | 658 | 158 |
| 5 | 164.5 | 822 | 322 |
| 6 | 164.5 | 987 | 487 |
| 7 | 164.5 | 1151 | 651 |
| 8 | 164.5 | 1316 | 816 |
| 9 | 164.5 | 1480 | 980 |
| 10 | 164.5 | 1645 | 1145 |
| 11 | 164.5 | 1809 | 1309 |
| 12 | 164.5 | 1974 | 1474 |
| 13 | 164.5 | 2138 | 1638 |
| 14 | 164.5 | 2303 | 1803 |
| 15 | 164.5 | 2467 | 1967 |

**Table 1** Net Present Value (NPV) Analysis after economic analysis and optimisation

# 4. Conclusions and Future Work

Based on the economic analysis, this proposed 250ktpa small-scale process would be commercially viable within an 8-10 year life of mine, and an important next step would be to conduct a Class 5 analysis to more closely determine the true cost of a possible plant.

Further works for this project include determination of appropriate reagent additives for Jameson Cell flotation and finalising the Air Classifier Excel simulation to more effectively model the possible separation of species considering specific gravity in addition to particle size.

In conjunction with Jiahao Zuo, further works would consider investigation of the feasibility of either Alumina as a saleable by-product of the pyrolytic process' waste stream, or the potential employment of the same calcinated slag as a means of carbon capture through the Urey reaction to potentially render the process carbon-neutral.

# 5. Acknowledgements

This research was made possible by the invaluable expertise and willingness to help of my mentors Prof. Hui Tong Chua and Dr Alan Ooi throughout this process. Special thanks are also extended to Rob Beeck, Jilly Hassack and Peter Phan from APIM for their endorsement and support of the project, and Glen Plummer, Ben Lamb, Simon Wilson and Ian Plant from APIM and Rain Lewis from Nagrom for their specific technical advice. I would also like to thank the CEEDWA team for providing this research opportunity. Lastly, my fellow CEED scholar Jiahao Zuo, who was a very helpful collaborator in the project as a whole.

# 6. References

Bulatovic, S. M. (2007) Classification of Flotation Reagents. Knovel. eBook ISBN: 9780080471372

Harbort, G. & Lawson, V. (2003). Jameson Cell Fundamentals – A Revised Perspective. *Minerals Engineering.* DOI: 10.1016/j.mineng.2003.06.008

Ker, P. (2022). Investigator raises alarm over Salt Lake Potash collapse. *Australian Financial Review.* https://www.afr.com/companies/mining/investigator-raises-alarm-over-salt-lake-potash-collapse-20220922-p5bkcr

Klymowsky, R (n.d.). High Pressure Grinding Rolls for Minerals. *ThyssenKrupp.* https://www.ausimm.com/globalassets/insights-and-resources/minerals-processing-toolbox/polysiushpgr.pdf

Tuckey, K. Bekker, E. Bornmann, F. (2016). A Cyclone for a Reason – Dense Media Cyclone Efficiency. Multotec at *Coal Preparation Congress.* https://www.multotec.com/public/uploads/files/media_files/file_8e52201c970bb2103855c8032904bb60.pdf

Venkatesan, S. Senthurpandian, V. K. Murugesan, S. Maibaum, W. & Ganapathy, M. N. K. (2006). Quality standards of CTC black teas as influenced by sources of potassium fertiliser. *Journal of the Science of Food and Agriculture.* 86:799–803 DOI: 10.1002/jsfa.2418

Zhang, Y. Hu, Y. Sun, N. Liu, R. Wang, Z. Wang, L. & Sun, W. (2018). Systematic Review of Feldspar Beneficiation and its Comprehensive Application. *Minerals Engineering.* https://doi.org/10.1016/j/mineng.2018.08.043