Hydrometallurgy Research & Development at the University of Queensland

Associate Professor
James Vaughan

XXVIII ENTMME
ENCONTRO NACIONAL DE TRATAMENTO DE MINÉRIOS E METALURGIA EXTRATIVA
4-8 Nov. 2019
Belo Horizonte | MG

https://researchers.uq.edu.au/researcher/2189
http://www.chemeng.uq.edu.au/hydrometallurgy
Presentation Outline

• Introduction to UQ / Chem Eng / Metallurgy / Hydrometallurgy

• Background Australian / Brazilian Refineries

• Motivation for Hydrometallurgy Research

• Examples Research Projects
  • Alumina
  • Nickel
  • Gold

The University of Queensland
Brisbane, Australia
UQ Snapshot

• Founded in 1909
• UQ ranks in the world’s top 50 universities
• Around 400 degree programs
• Over 50,000 students, 12,000 international students from over 140 countries
• More than 13,500 postgraduate students
• More than 12,000 PhD graduates
• Almost 7,000 full-time equivalent staff
• A global network of over 232,000 alumni in more than 160 countries
• #1 school of chemical engineering in Australia
• Scientia ac Labore
New Chemical Engineering
“Andrew N. Liveris” Building (opening 2021)


Building Site October 2019

Andrew Liveris
CEO of Dow Chemical (~2004-2018)
The dual major in chemical & metallurgical engineering provides the best of both worlds - a foundation in chemical engineering combined with specialisation in extractive metallurgy.
The treatment of ores, concentrates and other metal-bearing materials by wet processes usually involving the dissolution of some component, and its subsequent recovery from the solution.

**Research Infrastructure**
- Comprehensive autoclave facility
- Certified radiation facility
- Electrowinning / electrorefining / electrochemistry
- UV-VIS / TGA / AAS / ICP-OES
- FIMS/DMA for Hg
- Flow through thin film membrane filtration rig
- FIMLAB membrane synthesis / percristallisation
- Single particle optical sensing and laser sizers
- Factsage and HSC Chemistry software
- Centre for Microscopy and Microanalysis
- Brisbane Surface Analysis Facility
- Pyrosearch / JKMRC
- Bauxite and Alumina Technology Centre

**Projects**
- Refining mixed nickel-cobalt hydroxide precipitate
- Synergistic hydro-pyro processing of copper
- Separating radionuclides from copper concentrates
- Pressure oxidation chemistry
- Scandium hydrometallurgy
- Ion exchange resin technologies
- Inorganic membrane percristallisation
- Nickel agromining
- Processing high silica bauxites
- Value-added products

**People**
Professor Peter Hayes – Metallurgy Program Leader
James Vaughan – Associate Professor
Hong Peng – UQ Amplify Research Fellow
William Hawker – Lecturer
Weng Fu – Post Doctoral Researcher
James Gudgeon – Laboratory Manager
Kelly Byrne – Senior Research Technician
Stefan Lakemond – Senior Research Technician
David Mann – Senior Research Technician
Kimiya Bolouri – Senior Research Technician

**CSTR Pilot Plant**
- Sodium Oxalate
- Pressure Leaching
- Solvent Extraction
- Copper Cathode
Examples of Australian Refineries
Examples of Brazilian Refineries
Hydrometallurgy research and development drivers

- Decreasing ore grade
- Increasing ore complexity
- Increase efficiency of mature technologies
- New feed intermediates or secondary (recycled) materials
- Health, safety, environment, community
- Costs of waste disposal and rehabilitation
- Production of advanced / high purity materials / by-products
Examples of Research & Development Projects

• Alumina
  • The sandy DeSilication Product (DSP) process concept

• Nickel
  • Selective acid leaching of nickel from Mixed Ni-Co Hydroxide Precipitate (MHP)
  • Developments in nickel agromining

• Gold
  • A chemical-thermodynamic model for iron at pressure oxidation (POX) conditions
Alumina

Rio Tinto Yarwun Alumina Refinery, Queensland, Australia
Bayer Process

Bauxite → Digestion → Clarification → Precipitation → Calcination → Residue → Alumina

Bayer Liquor Cycle
Bayer Process - Digestion

**Gibbsite → Aluminate**
\[ \text{Al(OH)}_3 + \text{NaOH}_{(aq)} \rightarrow \text{NaAl(OH)}_4_{(aq)} \text{ at 110-150°C} \]

**Boehmite → Aluminate**
\[ \text{AlOOH} + \text{NaOH}_{(aq)} + \text{H}_2\text{O} \rightarrow \text{NaAl(OH)}_4_{(aq)} \text{ at 180-280°C} \]

**Kaolinite (Reactive Silica) → Sodalite DeSilication Product (DSP)**
\[ 3\text{Al}_2\text{(OH)}_4\text{Si}_2\text{O}_5 + 8\text{NaOH}_{(aq)} \rightarrow \text{Na}_8(\text{AlSiO}_4)_6(\text{OH})_2.2\text{H}_2\text{O} + 7\text{H}_2\text{O} \]

*DSP is costly in terms of lost NaOH*

*DSP in residue is an environmental challenge and an impediment to residue reprocessing*
Bayer process: 10 GJ/t-\(\text{Al}_2\text{O}_3\) but with BR sinter leach: 40 GJ/t-\(\text{Al}_2\text{O}_3\)!

Bauxite residue is very fine (< 2 µm), DSP cannot be physically separated

Growing DSP Particles

We have found conditions where DSP can be grown to > 30 µm

DSP size distribution as a function of reaction time

Coarse DSP agglomerates
The Sandy DSP Process

Vaughan J., Peng H., Seneviratne D., Hodge H., Hawker W., Hayes P., Staker W.
The Sandy DSP Process

- Lower mass flow to sinter-leach:
  
  Reduces energy requirement (OPEX) and size of the plant (CAPEX)

- Lower gangue mineral concentrations;
  
  Reduces reagent requirement associated with side reactions (OPEX)

Next step: continuous piloting, seeking industry partners
Light Metals 2020

This is an excellent opportunity to interact with experts from the Light Metals industry and academia from all over the world and get the latest update on key issues in the industry. Based on the importance of improving processes, reduce environmental impact and the global challenges in aluminum production.

Alumina & Bauxite topics:

*Bauxite Ore Characterisation, Bauxite Mining and Processing, Handling and Processing, Separation of Impurities, Sustainability and Environmental Issues, Processing Bauxite Residue*

https://www.tms.org/TMS2020
Nickel

First Quantum Minerals
Ravensthorpe nickel operation
Western Australia
Processing nickel laterite ore

Laterite ore → Ferronickel smelting / NPI

Laterite ore → Caron process

Laterite ore → Acid leaching
Processing nickel laterite ore

- Ferronickel smelting / NPI
- Caron process
- Acid leaching

- Direct Solvent Extraction
- Mixed Sulphide Precipitate
- Mixed Hydroxide Precipitate

- Goro
- Bulong
- Moa Bay
- Murrin Murrin
- Coral Bay
- Ambatovy
- Cawse
- Ravensthorpe
- Ramu
- Caldag
- Goro
Options for refining MHP

<table>
<thead>
<tr>
<th></th>
<th>Conventional AMMONIA LEACH - LIX 84I</th>
<th>Conventional ACID LEACH - C272</th>
<th>New SELECTIVE ACID LEACH</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Leach reagents</strong></td>
<td>NH$_3$/($\text{NH}_4$)$_2$CO$_3$</td>
<td>H$_2$SO$_4$</td>
<td>H$_2$SO$_4$ Oxidant</td>
</tr>
<tr>
<td><strong>MHP leach selectivity</strong></td>
<td>Mn</td>
<td>-</td>
<td>Mn, Co, Cu</td>
</tr>
<tr>
<td><strong>Leach robustness</strong></td>
<td>Sensitive to: MHP ageing; Fe, Al Oxidation Sulphate</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td><strong>Co/Ni solvent extraction</strong></td>
<td>Nickel selective</td>
<td>Cobalt selective</td>
<td>Not needed</td>
</tr>
</tbody>
</table>
Selective acid leaching of nickel from mixed hydroxide precipitate (MHP)

MHP
40% Ni
2% Co

H₂SO₄
Oxidant

Selective Acid Leach

Cobalt Concentrate
15% Ni
15% Co

Concentrated Nickel solution
100 g/L Ni
0.005 g/L Co
MHP oxidizing leach as a function of pH

![Graph showing leach extraction as a function of pH for Ni, Mg, Zn, Cu, Co, and Mn.](image)

**Conditions**
- 80°C
- 100% Oxidant
- 100 g-Ni/L-Slurry
- 30 min / pH adjust

**Reference**
Oxidation precipitation diagram (pH = 4.6)

Ni Selective Leach $E_h$

Selective acid leach technology licensed to

https://purebatterytech.com/
Powering the green energy revolution
2019 Pilot Plant

MHP
(40% Ni, 2% Co)

50 kg NiSO₄·6H₂O
(>99.9% Pure)

10 kg Cobalt Concentrate
(15% Co)
Refinery feasibility study complete

Selective Leach

Crystalliser

Reagents
Nickel agromining

Nickel agromining is envisaged to be a part of a progressive mining and rehabilitation strategy where local communities farm metals before and after conventional mining operations.

Nickel agromining

**Agromining chain**

1. **Soil prepared for hyperaccumulators’ growth**
   - Amendments
   - Hyperaccumulator plants are grown
   - Metals are extracted and translocated to the aerial parts

2. **Metals are extracted and purified**
   - Hydrometallurgy
   - Pellets, Ash

3. **Biomass in harvested and transformed**

4. **Metals are extracted and translocated to the aerial parts**

**Materials used**

- Serpentine soils
- Industrial waste
- Tailings
- Metal unexploited resources
- Metal compounds are recycled into industry

**Concentrations**

- 0.1% Ni
- 2% Ni

**Authors**

- J.L. Morel
- B. Laubie
Demonstration farms:
Malaysia, Albania, Austria, France, Greece, Spain

300 kg-Ni / (ha*year) production rates achieved

Phyllanthus rufuschaneyi
Alyssum Murale
Element localisation by synchrotron XFM-mXRF (Alyssum murale)
Example of a process for agromined nickel

2% Ni
Nickel Biomass

Air
Heat, Steam, CO₂

10% Ni

Potassium Carbonate Solution

Washed Ash

Sulphuric Acid

Potassium Hydroxide

40% Ni

Nickel Hydrosxide

Potassium Sulphate Solution

Potassium / Calcium Carbonate

Gypsum Rich Residue

Gold

Newcrest Lihir Gold Operation, Lihir Island, Papua New Guinea
Gold

Newcrest-UQ research team (2017)
Pressure Oxidation (POX)

Pressure oxidation is used to chemically liberate finely disseminated gold in sulfide minerals, typically pyrite / arsenopyrite.
Conventional understanding of iron phase stability in POX

Lack of reliable thermodynamic data at elevated temperatures
2L Ti Autoclave with internal Cooling / Sampling Port

Sample Flash Vessel and Pressure Filter

Ivana Ambrosia PhD research
Solubility of Basic Ferric Sulphate at 220°C

Fe\(\text{HSO}_4\text{SO}_4^0\)(a) + H\(_2\)O(l) ⇌ FeOH\text{HSO}_4(s) + H\text{SO}_4^-\)(a) + H\(^+\)(a)

*Unpublished results Ivana Ambrosia*
Solubility of Hematite at 220°C

FeHSO₄SO₄⁰(aq) ↔ Fe₂O₃

Fe(SO₄)₃⁰(aq) ↔ Fe₂O₃

Unpublished results Ivana Ambrosia
Using solubility data and simplifying assumptions a self-consistent thermodynamic database was produced providing predictive capabilities at 220°C
## Summary

<table>
<thead>
<tr>
<th></th>
<th>Sandy DSP</th>
<th>MHP Refining</th>
<th>Ni Agromining</th>
<th>POX Chemistry</th>
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<tbody>
<tr>
<td>Ore Grade</td>
<td></td>
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<tr>
<td>Ore Complexity</td>
<td></td>
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<tr>
<td>Increase Efficiency</td>
<td></td>
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<tr>
<td>New Feed</td>
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<td>HSEC</td>
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<td>Waste Management</td>
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<td>High Purity Products</td>
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Acknowledgements

Thanks to:

The researchers that contributed to the projects described.

The industry and granting agencies for supporting the projects.

Thanks for inviting me to this wonderful conference on extractive metallurgy.
Sponsors

Rio Tinto

BHP

Newcrest Mining Limited

Pure Battery Technologies

Oz Minerals

Australian Government
Australian Research Council

Uniquest

Advance Queensland

Queensland Government