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Uranium-REE Conference

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Lithium Processing Forum

13th Annual Uranium Event

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PROCEEDINGS OF
ALTA 2017 URANIUM-REE SESSIONS
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Lithium Processing Forum

25-26 May 2017

Perth, Australia

ISBN: 978-0-9925094-9-1

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Alan has over 40 years' experience in the metallurgical, mineral and chemical processing industries in Australasia, New Zealand, North and South America, Africa, Asia and Europe. He has worked in metallurgical consulting, project development, engineering/construction, plant operations, plant start-up and technology development. Projects and studies have involved copper, gold/silver, nickel/cobalt, uranium and base metals.

Since 1985, as an independent metallurgical consultant, Alan has as undertaken feasibility studies, project assessment, project development, supervision of testwork, flowsheet development, basic engineering, supervision of detailed engineering, plant commissioning and peer reviews and audits. Clients have included a variety of major and junior mining, exploration and engineering companies throughout Australia and overseas.

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ALTA 2017

Nickel-Cobalt-Copper, Uranium-REE and Gold-PM

Conference Report

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ALTA 2017 Uranium-REE Contents

ALTA 2017 Uranium-REE Contents

Uranium-REE Proceedings

Opening Address

RED BOOK 2016: INSIGHTS INTO URANIUM SUPPLY AND DEMAND

By

Adrienne Hanly and Peter Woods

Presenter and Corresponding Author

Dr Peter Woods
Team Leader, Uranium Resources and Production Subprogramme
International Atomic Energy Agency (IAEA), Austria

ABSTRACT

The 26th edition of “Uranium 2016: Resources, Production and Demand”, the “Red Book”, was released in November 2016. This well-recognised world reference on uranium was jointly prepared by the Nuclear Energy Agency of the Organization for Economic Co-operation and Development (OECD-NEA) and the International Atomic Energy Agency (IAEA). The report provides analyses and information from 49 countries. The new edition provides a thorough review of world uranium market fundamentals and presents data on global uranium exploration, resources, production and reactor-related requirements. It offers information on established uranium production centres and mine development plans, as well as projections of nuclear generating capacity and reactor related requirements through 2035.

Among the key findings in the latest report is that the total identified uranium resources as of 1 January 2015 increased by only 0.1 percent since 2013, with the resource base changing very little due to lower levels of investment and associated exploration efforts reflecting the currently depressed conditions of the global uranium market.

More than 20 countries around the globe produce uranium, with the largest producers Kazakhstan, Canada and Australia accounting for approximately two-thirds of world output. Global uranium mine production, meanwhile, had decreased by 4 percent between 2013 and 2015, though it remains above 2011 levels. The drop is due mainly to decreased production in Australia and lower output in Brazil, the Czech Republic, Malawi, Namibia and Niger. Kazakhstan, the world’s largest producer, continued to increase output, although at a slower pace.

Regarding future demand for nuclear power, the Red Book’s projections vary from region to region. While the Fukushima Daiichi accident led to a change of policies in some countries, nuclear power looks set to keep expanding globally both in low and high case scenarios, particularly in Asia.

While current uranium resources are more than adequate to meet the high growth scenario, doing so would “depend upon timely investments to turn resources into refined uranium ready for nuclear fuel production,” according to the report, adding that “significant investment and technical expertise” would be needed “to bring those resources to market”.

Keywords: Uranium Resources, Uranium Demand, OECD-NEA, IAEA, Red Book

Uranium-REE Proceedings

Keynote Address

PLANNING FOR A SUCCESSFUL URANIUM PILOT PLANT PROGRAM

By

Grenvil Dunn
Principal Process Engineer
Orway Mineral Consultants (WA) Pty Ltd, Australia

ABSTRACT

Many there are in Project Development and Engineering that consider Pilot Plant work before understanding all they should about their uranium containing feed ore(s). Premature commitment to piloting can, inter alia, result in the adoption of an inappropriate flowsheet in piloting. The consequence of this outcome can be far reaching; from project closure on the one hand because of cost and or schedule blow out, through to adopting a flowsheet yielding a sub-optimal return on the other.

This paper addresses the key aspects in the preparation and planning a pilot plant for a uranium project.

Keywords: Pilot Plant, Uranium, Sample Selection, Batch Testing, Variability Testing, Data Interpretation

Uranium-REE Proceedings

Project Development

AN UPDATE ON A-CAP RESOURCES' LETLHAKANE URANIUM PROJECT IN BOTSWANA

By

[1]Paul Woolrich, [2]Alan Taylor, [3]Grenvil Dunn and [4]Randall Pyper

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Corresponding Author

Paul Woolrich

Presenter

Alan Taylor

ABSTRACT

A-Cap Resources' Letlhakane Uranium Project in Botswana is globally one of the largest undeveloped uranium resources of 366 Mlbs U3O8. Extensive metallurgical testwork has been completed at SGS Perth and ANSTO over the last 8 years using a high acid heap leach process with an innovative SX/IX recovery process to achieve good recoveries. An extensive technical study completed in 2015 was used to support a Mining Licence application which was granted by the Botswana Government in September 2016 following EIA approval in May 2016.

Project economics, focusing on a higher grade resource consisting of 103.8Mt @ 450ppm U3O8 and targeting production of 9Mt ROM/annum averaging 3Mlbs/annum, is encouraging with operating costs of US$35/lb U3O8 for the first five years.

Future work will include optimising project economics by completing further feasibility studies including trial mining and grade control in selected areas to obtain better lithological controls on the mineralisation to refine the JORC compliant reserves and to confirm mining costs utilising surface miners. A-Cap also plans to carry out a Pilot Plant test programme using bulk drill samples to confirm process recoveries, operating and capital costs. These studies will be used to finalise mining and process design work.

Keywords: A-Cap, Letlhakane, Botswana, Uranium, Heap Leach, SX/IX, project economics, pilot plant

PILOT TESTWORK FOR THE PROCESS DEVELOPMENT OF THE MULGA ROCK PROJECT

By

Chad Czerny, Andrew Wydler and Tony Chamberlain

Vimy Resources Limited, Australia

Presenter and Corresponding Author

Chad Czerny

ABSTRACT

The pilot-scale testwork programs conducted Vimy Resources Limited (Vimy) in support of the Definitive Feasibility Study (DFS) for the Mulga Rock Project are presented, and discussed with focus on the process development.

The Mulga Rock Project is located approximately 240 km ENE of Kalgoorlie in the Great Victoria Desert of Western Australia. The Project will have the capacity to produce around 1,360 tpa of U_3O_8 (~3Mlb U_3O_8), contained in a uranyl peroxide product, for a Life-of-Mine of up to 17 years. The Pre-feasibility Study for the project was completed in Q4 of 2015, with the DFS being finalised in Q3 of 2017.

Extensive continuous piloting programs to demonstrate the proposed project flowsheets were conducted during 2016. Approximately 34 tonnes of blended ROM ores obtained from two open-pit trial mines excavated at the Ambassador East deposit were processed in these programs.

The piloting testwork undertaken to develop the DFS process flowsheet is summarised and the implications of the results for the process selection for beneficiation (by gravity separation) and for downstream hydrometallurgical recovery of uranium are discussed.

The beneficiation plant proposed for ore processing comprises of: a ROM ore mineral sizer, logwasher for ore slurrying and attritioning, fines removal using hydrocyclones, and upgrading of a middlings fraction by mass rejection of between 45 and 50% of a siliceous fraction using two stages of Upcurrent Classification (UCC), to produce a uranium-enriched concentrate, and barren rejects (sands). The rejects are returned to the pit voids. Upgraded ore is ground and thickened to produce a leach feed slurry which is forwarded to the Uranium Hydrometallurgical Plant.

Uranium is extracted from the leach feed by agitated tank sulphuric acid leaching followed by recovery of the dissolved uranium in a Resin-in-Pulp (RIP) circuit. The eluate obtained by resin elution is upgraded by Nano-filtration, followed by direct precipitation using hydrogen peroxide to produce a uranyl peroxide hydrate ($UO_4.xH_2O$) product.

Keywords: "Mulga Rock", Uranium, Beneficiation, Resin-In-Pulp, Uranyl Peroxide

METALLURGY OF THE NGUALLA RARE EARTH PROJECT – CHALLENGES, CHOICES AND INNOVATIONS

By

[1]Gavin Beer and [2]Roy Gordon

[1]Consulting Metallurgist, Australia
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Presenter and Corresponding Author

Gavin Beer

ABSTRACT

ASX listed Peak Resources Limited ("Peak") is developing the Ngualla Rare Earth Project in Tanzania. The project holds a JORC 2012 compliant Mineral Resource of 214.4 million tonnes at 2.15% rare earth oxides (REO) at +1% REO cut-off including a high grade weathered Bastnaesite Zone of 21.3 million tonnes of 4.75% at +1% REO cut-off. A Bankable Feasibility Study was recently completed based on a novel flowsheet which includes multiple stages beneficiation at Ngualla in Tanzania and calcination, selective leaching and separation into rare earth oxide products at Tees Valley in England.

This paper discusses how the metallurgical processes have been selected and developed to deal with the challenges of project logistics, processing technical risks and low rare earth prices which are faced by all existing and emerging rare earth producers.

Keywords: Process Development, Rare Earths, Bastnaesite, Alkali Roasting, Selective Leaching, Solvent Extraction

Uranium-REE Proceedings

Process Technology

IAEA'S OVERVIEW OF WORLDWIDE IN SITU LEACH URANIUM MINING

By

Peter Woods

International Atomic Energy Agency, Austria

Presenter and Corresponding Author

Peter Woods

ABSTRACT

In situ leach or leaching (ISL), also called in situ recovery (ISR) uranium mining, has become one of the standard production methods for this energy metal. ISL's application to amenable uranium deposits, in certain sedimentary formations, has grown over the last two decades in consequence of its competitive production costs and low surface impacts. A recent IAEA publication (In Situ Leach Uranium Mining: An Overview of Operations, IAEA Nuclear Energy Series No. NF-T-1.4 (2016)), provides an historical overview and shows how ISL experience around the world can be used to direct the development of technical activities, taking into account environmental considerations and emphasizing the economics of the process, from exploration, development and operations to responsible mine closure. The publication provides information on how to design, operate and regulate current and future projects safely and efficiently, with a view to maximizing performance and minimizing negative environmental impact.

Keywords: In Situ Leach, In Situ Leaching, In Situ Recovery, Uranium Mining, IAEA.

METALLURGICAL TEST WORK AND MODELLING TOWARDS UNDERSTANDING THE SUITABILITY OF A URANIUM DEPOSIT FOR IN-SITU PROCESSING

By

Laura Kuhar[1], Karl Bunney[1], Michael Jackson[1], Peter Austin[1], Jian Li[1], Dave Robinson[1], Henning Prommer[1,2], Jing Sun[2], Jess Oram[3] and Asha Rao[3]

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Presenter and Corresponding Author

Laura Kuhar

ABSTRACT

In-situ recovery (ISR) refers to the injection of lixiviant into an ore body, lixiviant contact and dissolution of metals from value and gangue minerals, and the recovery of the metals of interest at the surface through further processing. Despite the use of an ISR approach to the recovery of approximately half of globally produced uranium, the application of ISR to new regions of mineralisation is not without significant challenges. Knowledge of ore body deposit properties at a centimetre to metre scale would be ideal for the initial planning and the eventual recovery of metals in an ISR process. However, many of the tools required for the in-situ determination of these properties throughout the ore body and at depth do not exist. As the next-best alternative, downhole logs and laboratory tests and analysis of drilled (core) samples are the main sources of information for modelling and insight into the expected behaviour of the deposit during leaching, and provide a means of reducing the potential risks that could be faced during operation.

Test work was conducted on samples from a deposit with well-defined horizontal uranium mineralisation that exists in shallow unconsolidated sandstone, with a view to understanding the suitability of such a deposit for processing by ISR. Critical parameters included an understanding of the uranium and gangue deposit mineralogy and leach chemistry; the selection of an optimum lixiviant/oxidant system and a route for uranium recovery; an understanding of the hydrogeology of the deposit; and the development of a preliminary predictive reactive transport model. This paper will discuss the approach taken and describe some of the outcomes from this work.

Keywords: In-Situ Recovery, Characterisation, Leaching Tests, Hydrogeological modelling, Reactive transport modelling

R&D PROGRESS OF URANIUM MINING AND METALLURGICAL INDUSTRY IN CHINA

By

Yahui Tan, Wensheng Liao and Yijun Zeng

Beijing Research Institute of Chemical Engineering and Metallurgy Beijing (BRICEM), China

Presenter and Corresponding Author

Wensheng Liao

ABSTRACT

After 60 years of development, China has established its integrated technical system of uranium mining and metallurgical industry which is suitable for the characteristics of Chinese uranium resources. In recent years, the rapid development of Chinese nuclear power has given rise to an urgent demand for natural uranium products which enhances the innovation and development of Chinese uranium mining and metallurgy.

This paper introduces the latest research and development progress of uranium conventional mining and metallurgy, heap leaching, in-situ leaching, in-place leaching, safety and environmental protection, and comprehensive recovery of polymetals associated with uranium in China. And the R&D direction of Chinese uranium mining and metallurgy is proposed.

Keywords: uranium mining and metallurgy, research and development progress, China

PILOT STUDY ON URANIUM RECOVERY FROM VIETNAM URANIUM SANDSTONE LOW GRADE ORES BY THE HEAP LEACHING METHOD

By

Than Van Lien, Tran The Dinh, Nguyen Dinh Van, Nguyen Ba Tien and Nguyen Thi Kim Dung

Institute for Technology of Radioactive and Rare Elements (ITREE), Vietnam

Presenter and Corresponding Author

Than Van Lien

ABSTRACT

Heap leaching has been a well-known technique which is used in mining industry to recover valuable metals such as copper, nickel, gold and uranium from their low grade ores. Vietnam has uranium deposits located in the Nong Son Basin belonging Quang-Nam province in the middle area of the country, but the uranium content in these ores is relatively low (average from 0.01 % - 0.06%U) and the content of Fe in some deposits is high (nearly 2%). In this paper, several fundamental and applied studies on the column and box leaching behaviour of the Nong Son Basin uranium low grade are reported.

The heap leaching of low-grade uranium sandstone ores on a pilot scale, with capacities of 500 kg/batch and 3 000 kg/box of ore was carried out and the selective recovery of uranium from leach liquor was investigated. The optimum parameters for heap leaching were as follows: ores particle size 1 cm; acid H_2SO_4 concentration of the irrigation solution 50 – 75 g/L and irrigation flow rate was 10-30 $l/m^2.h$; oxidant MnO_2 powder 4 kg/t ore; necessary leaching duration for a batch was 15 days, and that for a box was 25 days with acid consumption of around 40 kg/ore tone. The leaching efficiency of uranium recovery was 75%.

The uranium concentration of leach liquor (in the case of box leaching) after 25 days was 1.25 gU/L, and the concentration of iron was 10 – 12 gFe/L. Treatment of leaching solution by ion-exchange using GS300 anion resin was conducted and was followed by precipitation to obtain yellowcake product with high quality of over 80% U_3O_8.

Key words: Uranium, low grade ores, heap-leaching, column and box tests, uranium recovery

ANION EXCHANGE OF URANIUM FROM SULFURIC ACID SOLUTION: ADSORPTION AND KINETICS CHARACTERISTICS

By

Yasser M. Khawassek

Nuclear Materials Authority, Egypt

Presenter and Corresponding Author

Yasser Khawassek

ABSTRACT

The present work deals with the adsorption of uranium from sulfuric acid solution using the strong base anion exchange Lewatit Mono Plus M500 (LMP) resin. Batch shaking sorption experiments are carried out to evaluate the performance of (LMP) anion exchange resin in the uranium adsorption. The adsorption parameters including contact time, pH, initial uranium concentration and temperature have actually been optimized. The physical parameters including the adsorption kinetics, the isotherm models and the thermodynamic data have also been determined to describe the nature of the uranium adsorption by the LMP resin. The working resin has been found to agree with both the pseudo second order reaction and the Langmuir isotherm.

Keywords: Uranium, Adsorption, sulfate liquor, ion-exchange, Lewatit

RECOVERY OF RARE EARTH, URANIUM AND THORIUM FROM INDUSTRY RESIDUE LEACHING EXPERIMENTS

By

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Corresponding Authors

Janúbia C.B.S. Amaral and Carolos A. Moraia

Presenter

Janúbia C.B.S. Amaral

ABSTRACT

This paper comprises the study of the recovery of rare earth elements (REE), uranium, and thorium from an industrial residue. REE are important in many areas of materials science, and their application in industry has grown rapidly in recent years. On the other hand, thorium and uranium are elements of great interest in the nuclear area. Thus, the recovery of these elements from secondary sources is important both from the point of view of sustainability and the environmental aspects. The residue used in this work was obtained by the liming treatment of an acid mine water generated in a closed uranium mining site. The main constituents of the residue are REE (4.55%), U (0.20%), Th (0.03%), Ca (15.8%), Al (9.63%), S (6.09%), Fe (4.13%), P (0.59%), and Si (1.92%). Additionally, Mn, Zn and K are present.

The leaching experiments were carried out under mechanical agitation, with temperature and final acidity control, using hydrochloric and sulphuric acid as leaching agent. The variables investigated were solids percentage, reaction time, temperature, and the acid/sample ratio. For the conditions evaluated, the recovery of REE was more efficient when hydrochloric acid was used. The dissolution of U and Th was practically the same for both acids. However, due to technical problems, such as solid – liquid separation, purity of the liquor and the fact that HCl is more aggressive than H_2SO_4, sulphuric acid was selected as the leaching agent. Using HCl in an acid/sample ratio of approximately 600 kg t^{-1}, 10% of solids and 2 hours of mechanical agitation at room temperature, a recovery of 99 % of rare earths, 90 % of Th and 98 % of U was obtained. When sulphuric acid was used with acid/sample ratio of 700 kg t^{-1}, the recovery of the metals was 93.6 % of rare earths, 81.1 % of thorium and 96.7 % of uranium. After the optimization of the leaching parameters, a sulphuric liquor containing 0.082 gL^{-1} Th, 0.35 gL^{-1} U, 9.1 gL^{-1} REE, 16 gL^{-1} Al, 7.8 gL^{-1} Fe, 0,47 gL^{-1} Ca, 0.75 gL^{-1} Zn and 0.1 gL^{-1} Si was obtained.

Keywords: Rare earth, Thorium, Uranium, Leaching, Industry Residues, Secondary Sources

JAROGAIN PROCESS FOR RECOVERING VALUE-ADDED METALS FROM RLE ZINC RESIDUE

By

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Presenter and Corresponding Author

Pertti Koukkari

ABSTRACT

Jarosite [typically of formula $MFe_3(SO_4)_2(OH)_6$, where M represents a metal cation (Na,K, Pb/2 etc.) or ammonium is produced as leach residue in several hydrometallurgical base metal processes. Its most abundant source is zinc RLE (roast-leach-electrolysis) process. In the recent history, RLE jarosite has been usually compiled in the plant vicinity and is generally considered as problem waste.

Even though RLE zinc producers are looking for novel solutions to avoid excess formation of leach residues, the estimated rate of stockpiling is further up to 5 million tonnes/yr worldwide. While zinc ore typically is a carrier of many other metals, the content of both commercial and critical metals in such heaps is significant. Thus, e.g. gallium and indium are readily precipitated in jarosite-type compounds and are often present in considerable amounts in the jarosite heaps. The analysis of a typical jarosite stack shows content of zinc 2%, lead up to 3%, silver 150 g/t, gold 0.5 g/t, indium 100 g/t and gallium 40 g/t. Iron content is at least 15%. Such compositions are comparable with the present day commercial ores.

Major research of jarosite processing so far has been focusing on its bulk metals recovery by pyrometallurgical methods, while stabilizing the formed slag to be utilized as a construction or landfilling component. Yet, as the stack necessarily contains also poisonous constituents (As, Cd), such developments have had a limited success. Thus, interest in reprocessing jarosite to recycled value added products has also been increasing during the last few years [(1)]. A hydrometallurgical route for recovering and recycling the metal contents of jarosite has been proposed earlier [(2)]. In the present work, a hydrometallurgical flow sheet consisting of a coupled treatment of jarosite and zinc containing electric arc furnace (EAF) dust is presented [(3)].

The experimental proof-of-concept of key stages of the holistic hydrometallurgical recovery of metals present in jarosite and EAF dust (Fe, Zn, Pb) as well as value added components including Ag, In and Ga as concentrates is outlined when using industrial residues as raw materials. Economic potential and environmental benefits of the process will be discussed.

Keywords: Jarosite Processing, Acid Leach, Recovery of Metal Values, Hydrometallurgy, Holistic Process, Proof of Concept

SEPARATION OF THORIUM, URANIUM AND RARE EARTH ELEMENTS FROM SULPHURIC LIQUOR

By

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Presenter and Corresponding Author

Carlos A. Morais

ABSTRACT

This paper describes the study of separation of thorium and uranium from rare earths elements and some contaminants present in sulphuric liquor through a solvent extraction technique. The liquor was generated by dissolution of an industrial residue obtained by the neutralization of the acid water generated in an old uranium mine in Caldas, State of Minas Gerais – Brazil. The solvent extraction process was adopted in order to separate Th and U from the rare earth elements and the other metals present in the liquor. The influence of the type and concentration of the extractant, acidity of the liquor, aqueous/organic volumetric ratio and type and concentration of the stripping solution were investigated. The experiments were carried out using a liquor containing 0.38 gL^{-1} of U, 0.082 gL^{-1} of Th, 9.1 gL^{-1} of REE, 16 gL^{-1} of Al, 7.8 gL^{-1} of Fe, 0.47 gL^{-1} of Ca, 1.9 gL^{-1} of Mn, 0.10 gL^{-1} of Si, 0.75 gL^{-1} of Zn, 131 gL^{-1} of SO_4^{2-} among other impurities. Uranium and thorium can be extracted separately or simultaneously, using amines as extractants. For the simultaneous extraction, the separation of Th and U can be done from the stripped solution, where the metals are in higher concentration. The results showed that 97.1% of uranium and 94.4% of thorium were extracted with a Primene®JM-T and Alamine®336 mixture. Separation factors of 142 for Th/RE and 292 for U/RE were achieved. In the case of the extraction of thorium and uranium separately, the separation factor for Th/U was 151. The separation factor for Fe/REE was 10.3 for Primene®JM-T 0.05 $molL^{-1}$ and 7.7 for Primene®JM-T 0.2 and 0.3 $molL^{-1}$. The extraction of the other metals present in the liquor was less than 0.2%.

Keywords: Uranium extraction, Thorium extraction, Rare earth sulphuric liquor, Separation of thorium and uranium.

Uranium-REE Proceedings

Lithium Processing Forum

APPLICATIONS OF ADVANCED ANALYTICAL AND MASS SPECTROMETRY TECHNIQUES TO THE CHARACTERISATION OF LITHIUM BEARING ORES

By

Mark G. Aylmore[1], Kelly Merigot[1], William D.A. Rickard[1,4], David W. Saxey[1,2,4], Denis Fougerouse[2,3,4], Steven M. Reddy[2,3,4], Zakaria Quadir[1], Noreen Evans[1,2,3], Bradley McDonald[1,3], Brent I.A. McInnes[1, 2], Enej Catovic[5], Peter Spitalny[5]

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Presenter
William Rickard

ABSTRACT

Lithium has become a critical material for many modern technologies, most particularly in rechargeable batteries for portable electronic devices. The ability to extract lithium from ores economically is essential to creating a sustainable lithium production. However, a comprehensive understanding of the deportment of lithium and associated minerals in some ore bodies is limited. Lithium is a light element which makes it very difficult to analyse using conventional x-ray based methods and therefore requires special analytical techniques to quantify the abundance and distribution in minerals. In addition, the deportment of other elements (e.g., Rb, Cs, B, Be, Fe, Al, Mn, F) associated with minerals within pegmatite deposits also need to be considered in process development.

This presentation demonstrates the capabilities of the integrated use of the John de Laeter Centre's state-of-the-art analytical techniques to characterise lithium-bearing pegmatite ores. The mineralogy, mineral associations and liberation characteristics of both ore-bearing and gangue minerals in spodumene and lithium bearing micaceous pegmatites were characterised using a Tescan integrated mineral analyser. The distribution of lithium and other elements within the minerals were defined in a suite of ores using a combination of Laser-ablation ICP-MS, field emission scanning electron microscopy techniques with ESBD and ToF-SIMS capabilities, as well as Atom Probe Microscopy for 3D atomic imaging to identify lithium zonation within mineral matrices.

Keywords: Lithium, Li-bearing ores, automated mineralogy, LCT pegmatite, ToF-SIMS, TIMA, Atom Probe microscopy

ONLINE LITHIUM ANALYSIS IN SPODUMENE CONCENTRATION

By

Lauri Koresaar and Juha Timperi

Outotec, Finland

Presenter and Corresponding Author

Lauri Koresaar

ABSTRACT

The requirement for lithium has grown recently due to the increased demand in battery applications. Due to the increasing demand for lithium, hard rock sources have become an economical source for lithium production. Compared to brine sources, the hard rock lithium production utilises the same beneficiation methods as traditional minerals beneficiation. Effective process control can be regarded as one of the fastest paying investments for a minerals processing plant. Process optimisation in flotation circuits requires constant feedback of the process state. Spodumene ($LiAl(SiO_3)_2$ laboratory analysis can be very time consuming and the results do not represent the true process state due to the delay. Standard X-Ray analysers, used in base metals processing, fail to measure the weak X-Rays from lithium. Good results from online lithium measurement have been achieved using an analyser based on Laser-Induced Breakdown Spectroscopy (LIBS). LIBS uses a high energy laser to generate plasma in the sample surface, the light emitted from the plasma is then analysed using Optical Emission Spectroscopy (OES). Promising results have been obtained for simultaneous measurement of Li, Al, Fe, Si, K, Ca and Mg for a spodumene concentrator. The online measurement results are planned for controlling magnetic separation and flotation performance.

Keywords: Spodumene Concentration, Process Control, Online Analysis, Laser-Induced Breakdown Spectroscopy

SPECIALIZED IMPELLERS FOR HYDROMETALLURGICAL PROCESSING APPLICATIONS WITH FOCUS ON LITHIUM

By

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ABSTRACT

Hydrometallurgical processing of Lithium, rare earths and uranium has gained in importance as the production must keep up with growing world-wide demand and the increased requirement for product qualities. Although significant improvements have been made for non-ferrous and precious metals processing, adapted or new agitator solutions had to be provided for these applications.

For processing of battery grade lithium carbonate, to name an example, the crystallization and gassed units are crucial for the overall plant performance. Unlike precipitation steps, crystal morphology and particle size distribution in crystallizers must be precisely controlled. This paper will present the newly developed EKATO Torusjet, which is an improved draft tube impeller with a significantly higher efficiency compared to standard solutions. For the same motor power it achieves higher pumping rates, a better degree of slurry homogeneity and an improved surface renewal, which finally leads to a more uniform crystal growth. Due to the optimized blade geometry the local and overall shear rates are decreased minimizing crystal breakage and decreasing abrasion issues.

For gassed applications, especially if a very high degree of gas utilization must be achieved, EKATO has successfully applied the self-inducing gassing turbine EKATO Gasjet. This paper will present different examples from minerals processing, e.g. for the carbonization/ de-carbonization step at a lithium carbonate processing plant in which carbon dioxide gas can be used in a closed loop system.

Key words: crystallization, self-inducing gassing impeller, gas utilization, agitator, draft tube

REVIEW OF LITHIUM PRE-CONCENTRATION, EXTRACTION, SEPARATION AND OR PURIFICATION USING DOW WATER AND PROCESS SOLUTIONS TECHNOLOGIES

By

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ABSTRACT

A review of Dow Water and Process Solutions technologies capability for:

1. the pre-treatment and concentration of Lithium brines using FILMTEC™ - nano filtration and reverse osmosis membranes

2. the extraction, separation and or purification of Lithium solutions using DOWEX™ / AMBERSEP™ - ion exchange resins.

Keywords: Lithium, Reverse Osmosis, Nano Filtration, Ion Exchange Resin

THE CASE FOR SECONDARY LITHIUM MINERAL PROJECTS

By

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ABSTRACT

In this paper secondary lithium mineral deposits are considered to be those hosting predominantly non-spodumene minerals. These include lithium bearing micas, sedimentary deposits such as clays and jadarite. In general, these resources have a lower grade of lithium and the amount of ore that needs to be processed is significantly more than for a corresponding spodumene producer. A common perception is that this will result in a higher operating cost as a result of higher energy and reagent costs and therefore, as long as there are additional spodumene resources, there is little chance of a secondary lithium mineral resource being developed.

This paper discusses the challenges facing the companies producing lithium from brines as well as from spodumene. The question is asked if the new spodumene concentrates should be regarded as identical to the Talison SC6.0 concentrate, which currently is the industry standard. A comparison of the cash cost to produce lithium carbonate is made between four spodumene concentrate supply cases with significant variation in outcomes. Using the same basis, a comparison is then also made with the proposed production of lithium carbonate from a Zinnwaldite concentrate from European Metals Holding's Cinovec project. While the attractive economics of this project are in part attributable to project specific factors, such as its by-product credits and geographic location, they support the case for consideration of secondary lithium mineral projects for development to supply lithium to fill the growing demand for lithium chemicals.

Keywords: Lithium recovery, lithium extraction, spodumene, zinnwaldite, lepidolite, hectorite, clays, lithium micas, mica, operating cost, project development

A BROAD LOOK AT LITHIUM EXTRACTION

By

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ABSTRACT

This paper examines a number of published processes for the production of lithium carbonate or hydroxide from ore and brine. The circuits are described and the capital and operating costs for each, as published by the developers, are summarized and compared.

The economics associated with the production of lithium carbonate and lithium hydroxide via established technology are discussed in the context of the manufacture of lithium-ion batteries.

Keywords: Lithium, extraction, spodumene, brine, capex, opex.

LITHIUM EXTRACTION FROM COMPLEX SILICATES

By

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ABSTRACT

The demand for high purity battery grade lithium carbonate is expected to grow significantly in the near term. The lithium-ion battery sector is one of the fastest growing and largest consumers of lithium. Lithium-ion batteries have superior energy density, are more efficient and environmentally friendly than traditional acid batteries and the cost is falling based on innovation and technical development.

Lithium ores of major economic importance are spodumene ($Li_2O.Al_2O_3.4SiO_2$), lepidolite ($3LiF.K_2.2Al_2O_3).7SiO_2$), ambylgonoite ($Li.Al.F.PO_4$), petalite ($LiAlSi_4O_{10}$,), zinnwaldite (KLiFeAl(AlSi3)O10(OH,F)2) and brines (Li.Na.PO4). Spodumene because of its abundance is the most important source of lithium.

The metallurgy of lithium ores is very ore specific depending on lithology and the lithium silicate minerals are generally refractory. Physical concentration using dense media or flotation is common followed by hydrometallurgical process routes. The hydrometallurgical difficulties specifically managing impurities is ore specific and often means that some lithium ores are not economic. At the same time some lithium ores contain valuable by products which can enhance the project economics if saleable products can be produced.

Keywords: Pegmatite, spodumene, lepidolite, beneficiation, dense media separation, flotation, magnetic separation, micas, liberation, calcination, leaching, purification, lithium hydroxide, lithium carbonate, alpha spodumene, beta spodumene, battery grade lithium carbonate.

LITHIUM PROCESS FLOWSHEETS - CHALLENGES AND OPPORTUNITIES

By

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Chris Griffith

ABSTRACT

Over the last 4 years, ANSTO Minerals has undertaken a significant amount of work on the processing of lithium deposits to produce saleable lithium chemical concentrates. This work has encompassed everything from bench top process development through to continuous piloting (1-2 kg/h solid feed and 5-10 L/h liquor feed), and demonstration plant design and operation (2 m3/h brine feed).

Our execution of these programs has provided an excellent opportunity to compare and contrast the processing of brine and hard rock lithium deposits. It has become clear from this work that the processing of Li resources using conventional process flowsheets poses a number of challenges depending on the grade, mineralogy (for hard rock), impurity suite and location of the deposit. These challenges have in turn highlighted a number of opportunities for improvement, which we have examined for our clients.

Table I displays a brief summary of the main advantages, challenges and opportunities for conventional processing flowsheets for brine and hard rock deposits.

In the presentation we will provide an overview of the conventional process flowsheets for brine and hard rock deposits, plus several alternative process flowsheets, which are currently being developed for both types of projects.

Table I Brine and Hard Rock Process Flowsheets: Advantages, Challenges and Opportunities

Brine Processing		
Advantages	**Challenges**	**Opportunities**
Abundant resources	Resource estimation	Raw brine processing
By-product production	Resource utilisation	Integrated / efficient process
'Simple' processing	Remote location logistics	Li selective concentration step
↓Energy requirement	Time to production (>1 y)	
Proven production	Production losses	
	↑Mg:Li ratio	
Hard Rock Processing		
Advantages	**Challenges**	**Opportunities**
Abundant primary resources	Comminution	↓Temp. processes
Abundant secondary resources	Comparatively ↓grade	Spodumene hyromet. process
Resource estimation	↑Temp. - ↑Energy	Integrated / efficient processes
Supply diversity	Broad impurity suite	Li selective concentration step
Ready beneficiation		
By-product production		
Proven production		

Keywords: Lithium, Processing

HYDROMETALLURGICAL PROCESSES FOR THE RECOVERYOF LITHIUM FROM SILICATES

by

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ABSTRACT

Lithium Australia NL has been developing a number of hydrometallurgical process flowsheets for the recovery of lithium from silicates. The most advanced of these, the halogen-based SiLeach™ process, was developed specifically for the digestion of spodumene, a refractory lithium pyroxene previously able to be processed only by roasting, followed by sulphation bake and water leach. The SiLeach™ process, which relies on the reaction of halogens with silicon-oxygen bonds, is widely applicable to the dissolution of all categories of silicate minerals and has found practical application in the processing of lithium micas. SiLeach™ is currently being commercialised, utilising pilot facilities established at ANSTO Minerals (a division of the Australian Nuclear Science and Technology Organisation).

With SiLeach™, the halogens can be added to the process slurry in a number of ways. However, the preferred method is via the addition of ground fluorine minerals (which may include the lithium micas themselves) to the process slurry prior to the addition of sulphuric acid. Due to the kinetics of competing reactions, this sequence allows the momentary generation of fluoride in solution – and its almost instantaneous reaction with the silicates – without any accumulation of hydrogen fluoride (‘HF’) in the slurry. Process plant operations can be accomplished without the hazards often considered a risk with fluorine-based processes.

The SiLeach™ process is capable of recovering a wide range of by-products, as all metals in the target silicate are dissolved. The low energy requirements of the process, as well as by-product credits, enhance the economics, which may result in lithium production costs using SiLeach™ to be among the lowest currently experienced.

SiLeach™ has the potential to provide access to a wide range of plant feed previously not considered viable. Such feed includes low-grade spodumene concentrates and micas as primary feed sources. Furthermore, vast quantities of lithium minerals currently discharged as tailings from non-lithium mining operations create very attractive targets for the application of this type of technology. Utilisation of these materials as lithium sources will greatly enhance the sustainability of the lithium industry.

Keywords: SiLeach™, lithium, spodumene, mica, halogen, fluorine, hydrometallurgy

Uranium-REE Proceedings

Not Presented

Included in proceedings but not presented

QUANTITATIVE ANALYSIS OF URANIUM AND THORIUM CONTAINING MATERIALS USING INDUSTRIAL ON-LINE XRF ANALYZER

By

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ABSTRACT

Precise and accurate determination of uranium (U) and thorium (Th) in mineral materials in real time is essential for many industrial processes. Laboratory and pilot tests show the possibility to provide acceptable measurement accuracy at high representativeness and speed of analytical feedback using the online X-ray fluorescence analysis. Results are demonstrated for continuous measurement of U and Th at wide ranges of concentrations (from 100 ppm up to several %) in various materials: rutile and zircon heavy mineral sands; phosphate rock and fertilizers; limestone rocks as unconventional U and Th resources; monazite concentrate as U and Th associated resources; U ore residues after heap-leaching, and other similar materials.

Keywords: uranium and thorium, mining, mineral materials, online XRF analysis, industrial conveyor analyzer, pilot test, analytical parameters of measurement.

Included in proceedings but not presented

ALUMINUM OXIDE GRAFTED KAOLINITE FOR EFFICIENT URANIUM REMOVAL FROM AQUEOUS SOLUTION

By

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ABSTRACT

Due to extensive diversity of nuclear applications, efficient adsorbents are highly required for radioactive liquid waste treatment. In this investigation, costless and simple approach for removing uranium from liquid waste by aluminum oxide grafted kaolinite (AOGK) was stated. The influences of contact time, solution pH, initial uranium concentration, adsorption temperature, adsorbent amount (dose) on the adsorption of uranium (VI) ions from radioactive liquid waste were investigated. The theoretical capacity of AOGK adsorbent is about 95 mg/g AOGK. The optimum adsorption conditions were recommended. About 95% of the loaded Uranium (VI) on AOGK adsorbent has been eluted by ascorbic acid as an efficient eluent.

Keywords: uranium, removal, aqueous solution, grafted kaolinite

Included in proceedings but not presented

STUDY ON REES LEACHED IN PHOSPHATE CONCENTRATE WITH PHOSPHORIC ACID

By

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ABSTRACT

A new hydrometallurgical leaching process, which dissolves REES with phosphoric acid, was proposed and investigated. It studied the effects of H_3PO_4 concentration, temperature, reaction time, and liquid-solid ratio on REES leached. The results showed that an extraction of about 90% was achieved under the leaching conditions: 25% H_3PO_4, 65°C, liquid-solid ratio 10, and reaction time of 8 hours. SEM and XRD analysis indicated that no new reaction solid product was formed on the surface of leaching residue particles. The dissolution kinetics of REES with phosphoric acid solution was found to fit the shrinking core model. The kinetic study indicated that REES leached was controlled by the interfacial chemical reaction in the whole leach process. The apparent activation energy was 46.6 kJ/mol and a semi-empirical rate equation was obtained to describe the process.

Keywords: Phosphate, phosphoric acid, REES, leaching