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SUPPORTING GOOD PRACTICE AND DEVELOPMENT OF URANIUM IN SITU LEACH MINING WORLDWIDE – IAEA INVOLVEMENT

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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. The IAEA has been working with its Member States regarding ISL of uranium for several decades, with a number of publications from 1989 to 2016 and another in preparation. Specialist meetings on ISL uranium mining have been held in Kazakhstan, China, Vienna and elsewhere.

As with other technologies within the uranium production cycle, the IAEA is actively supporting good practice in the ISL technique worldwide. Its safety standards for radiation protection and radioactive waste management are well known and provide standards and guidance in these important aspects. Further, it produces guidance and acts as a broker of information on technological, geological, regulatory and environmental aspects of the different phases of the uranium production cycle. Technical Cooperation projects are conducted throughout the world on such topics to facilitate improved practices around the globe.

Early efforts of the IAEA in the field of ISL uranium mining included capturing the experience of former Eastern Bloc countries into readily accessible, published form in English. An overview and review of international experience was published in 2016. However, through contributed papers at Technical Meetings of various kinds and ISL sessions of its international uranium symposiums (most recently in 2009, 2014 and 2018), the IAEA has been a conduit for the exchange of current ideas, practices and innovations in the international uranium mining scene. Both experienced and new operators, participants from potential future ISL uranium producers, suppliers, researchers, regulators and others not only document past and current practices but look to innovation and future trends.

Although the basic technology of ISL uranium mining has been established for decades, significant improvements in many areas are apparent. The industry cannot 'rest on its laurels' and ongoing improvements to the technique are and will be required to enable it to maintain its place as a major uranium production method. The experience in ISL uranium mining is available to inform efforts to implement ISR mining of other commodities. No less, in turn, ISL uranium mining stands to learn from the innovations made and lessons learned as the equivalent technique is developed for those other commodities.

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

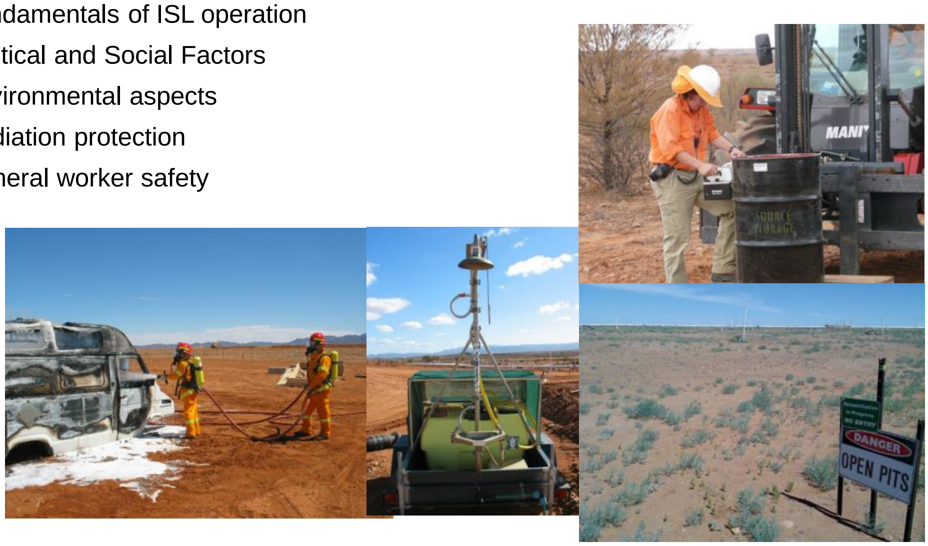
Introduction

- The IAEA has held meetings and produced publications specifically on uranium ISL/ISR mining since the 1980s

- Many individual papers by many authors on ISL/ISR have been published, and ISL/ISR covered as part of more general publications on uranium mining

Important considerations

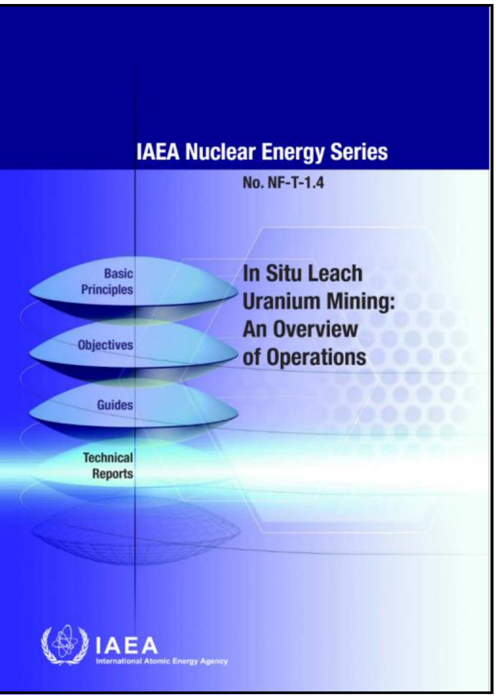
- Fundamentals of ISL operation
- Political and Social Factors
- Environmental aspects
- Radiation protection
- General worker safety



Photos P. Woods, at Beverley and Four Mile uranium projects, Australia

ISL U Mining: An Overview of Operations

- Introduction
- Resource and Reserve Definition
- Fundamentals of In Situ Leach Uranium Mining
- Historical Developments of In Situ Leach Mining
- Political and Social Factors
- Compilation of Project Data
- Outlook
- 186 References (mostly pre 2013), Glossary, Conversion Factors, List of Abbreviations
- Annexes covering 58 individual or group deposits (PDF only)
- Free download at: pub.iaea.org/books/iaeabooks/10974/In-Situ-Leach-Uranium-Mining-An-Overview-of-Operations



Some earlier IAEA ISL publications

Year	Title	Series
2005	Guidebook on Environmental Impact Assessment for In Situ Leach Mining Projects	TECDOC-1428
2004	Recent developments in uranium resources and production with emphasis on in situ leach mining	TECDOC-1396
2002	Working Material In Situ Uranium Mining	WM-T1-TC-975
2001	Manual of Acid In Situ Leach Uranium Mining Technology	TECDOC-1239
1997	Environmental Impact Assessment for Uranium Mine, Mill and In Situ Leach Projects	TECDOC-979
1993	Uranium In Situ Leaching	TECDOC-720
1992	New developments in uranium exploration, resources, production and demand	TECDOC-650
1989	In Situ Leaching of Uranium: Technical, Environmental and Economic Aspects	TECDOC-492

Other ISL document in preparation

- **Safety Aspects of Development and Management of Uranium Production by In Situ Leaching** (or similar title)
  - This will concentrate on radiation safety aspects of ISL/ISR U production
  - Planned to be published in 2018

International Overview

- 14 countries involved, 4 with testing only
- Main current producers with ISL
  - Kazakhstan
  - Uzbekistan
  - USA
  - Australia
  - Russian Federation
  - China
- Prospective newcomers
  - e.g. Turkey, Mongolia, Tanzania
- Prospective expansion
  - China, Russian Federation

Packed U concentrate, Kazakhstan (source: KazAtomProm)

Recovery technology options

- Acidic/alkaline leaching
- Ion exchange/solvent extraction recovery
- Satellite operations

Acid leach with SX, Honeymoon, Aust. (photo: U1)

Alkaline leach with IX, Alta Mesa, Texas (P. Woods)

Established Technology

- The basic technology of alkaline and acid ISL uranium mining has not changed greatly after the first decade or two, where various alkalis and acids were trialled until the industry settled on carbonate–bicarbonate and sulfuric acid, combined mostly with ion exchange (to a lesser extent solvent extraction)
- An oxidizing agent is usually added, ranging from air and oxygen to hydrogen peroxide or ferric iron, and others
- Automation of operations has been introduced for about 2 decades

Emerging Technology (1)

- Innovations in
  - Well design, e.g. rescreening, dual-purpose
  - Pumping arrangements
  - Advances in well re-development (cleaning, restoring flow)
  - ‘Tuning’ of lixiviant
  - Resins suitable for use with high salinity/chlorinity
  - Numerical modelling of hydrogeology, geochemistry/extraction
  - Advanced geophysics, e.g.
    - advanced Prompt Fission Neutron (PFN) probes, combinations of PFN with other methods
    - Shallow seismic methods

Emerging Technology (2)

“Further developments in mining solution additives to reduce costs, environmental impact or speed groundwater remediation, where active intervention is required, will be considered. All will require field demonstration before they would be seriously considered by producers or accepted by regulators.”

Environmental management

"…identifying, understanding, managing and minimizing potential adverse impacts, good environmental management contributes to:

- Improved environmental outcomes;
- Demonstrated good corporate governance and accountability;
- Improved socioeconomic outcomes;
- Improved liability management;
- Reduced closure and rehabilitation costs."

Some critics

- Academic Journals, e.g.
  - "Critical review of acid in situ leach uranium mining: 1. USA and Australia, & 2. Soviet Block and Asia" (Mudd, 2001a,b).
- Environmentalist Magazines, e.g.
  - "Uranium Miners Turning Water Into Liquid Waste" Green (2010)
  - "Nuclear Fuel's Dirty Beginnings: Environmental Damage and Public Health Risks From Uranium Mining in the American West" Fettus & McKinzie (2012)

Some other assessments - Beverley

- CSIRO Land and Water [Taylor et al.], Review of environmental impacts of the acid in-situ leach uranium mining process (2004), report to the South Australian Environment Protection Authority
  - Regarding injection of waste water into the mining aquifer, '…as this groundwater has no apparent beneficial use other than by the mining industry, this method of disposal is preferable to surface disposal'
- Garrett, P. [Minister for Environment] (2008) Press Release
  - "The way in which Heathgate manages mining fluids and the disposal of liquid wastes has been confirmed by the CSIRO and Geoscience Australia as world's best practice and endorsed by the Chief Scientist."

Need to minimize on-going legacies/water treatment

Historic contamination from ISL U mining is best publicised from the Straz area, Czech Republic.

Water treatment from former Hamr and Straz uranium mines, Czech Republic, 1996 – 2037/42 (expected)

Photos P. Woods Sep. 2012, Aug. 2013
Left to right: Groundwater extraction well for clean up at Straz; Straz main treatment plant; regional treatment plant, former satellite mine (U/G) to Rozna mine

What does the IAEA Overview Document discuss? (1)

- Remediation of residual mining (and in some cases disposal) solution that remains in the mined aquifer at the completion of mining may or may not be required depending on:
  - the prevailing regulatory environment,
  - the original pre-mining quality of groundwater in the aquifer intended for mining,
  - the known or expected end-use of the aquifer, the connectedness of the mined aquifer to other groundwater resources, users or the environment, and
  - the likelihood of migration of residual mining or disposal water.

What does the IAEA Overview Document discuss? (2)

- The requirement for or acceptance of little or no remediation other then ‘monitored natural attenuation’ of groundwater after ISL mining has been a major source of discussion and sometimes disagreement between miners, regulators, external stakeholders and NGOs.

- Where remediation is required, the target water quality is also a point of discussion; should it be to meet a given use category (e.g. suitable for stock or domestic water supply, with or without further treatment) or returned to (close to) the original water quality within certain ranges?

What does the IAEA Overview Document discuss? (3)

- Factors where groundwater remediation is **more likely** to be scientifically, regulatorily or socially required include:

  1) Groundwater in the aquifer targeted for mining is used by others in the targeted area or nearby in the same aquifer, in a hydraulically well-connected aquifer, or where there is a non-negligible risk of adverse effects on those users.

  2) Original groundwater quality meets guidelines for certain uses but is not currently being used in the vicinity or from aquifers that might reasonably be adversely affected.

  3) Affected groundwater supports natural springs or otherwise enters surface waterways, lakes or marine environments with a non-negligible risk of adverse effects.

What does the IAEA Overview Document discuss? (4)

- Factors where remediation is **less likely** to be scientifically, regulatory or socially required are:

  1) Groundwater in the aquifer targeted for mining is in poor or negligible hydraulic connection with surrounding aquifers.

  2) Groundwater in the aquifer targeted for mining is not used by others in the targeted area or nearby in the same aquifer, nor a hydraulically connected aquifer, or where there is a negligible risk of adverse effects on those users.

  3) Original groundwater quality does not meets guidelines for certain ‘higher’ uses such as domestic, irrigation or pastoral use, perhaps due to high salinity, high natural radioactivity or the natural presence of toxic elements such as arsenic or fluorine.

Factors where remediation is less likely to be scientifically, regulatory or socially required are (cont'd):

4) Treatment of affected water may create wastes that are more problematic to dispose of safely compared to keeping the affected water in the mined-out aquifer or specific disposal aquifer.

5) The geochemistry of natural sediments and rock materials surrounding the mined aquifer is such that any migrating mining or waste solutions will be neutralized and/or problematic constituents significantly retarded.

6) Long pathways (time and distance) to any known or potential discharge point of the aquifer being mined.

Remediation Methods

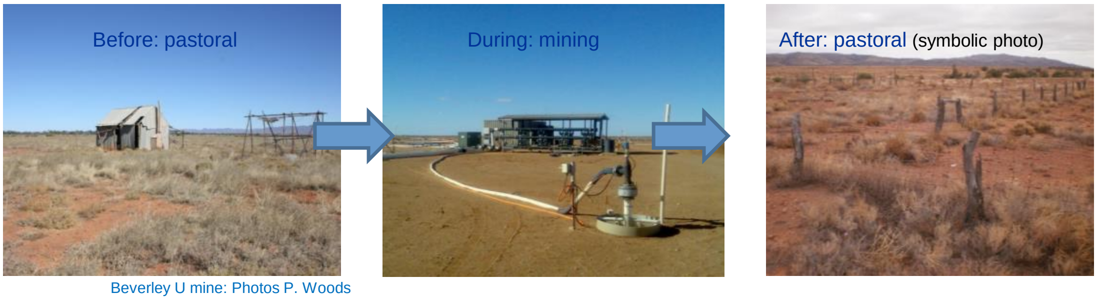
- Cleaning via reverse osmosis or other desalination technologies
- Cleaning by ex- or in-situ precipitation with reagents
- Washing with a reagent to counter induced acidity/alkalinity
- Washing with a reagent to induce chemically reducing conditions
- Washing with formation water ('groundwater flush')
- Deliberately drawing mining solution through adjacent un-mined formation to consume acidity/alkalinity and cause the precipitation of metals by reaction with natural components of the aquifer substrate
- Creation of a reactive in-situ neutralizing barrier down-gradient of the affected groundwater that will speed the neutralization of mining solution as it passes through the barrier
- Other possibilities, and possible combinations of the above

Notes on Groundwater Remediation

- For some operations in the USA, demonstration of the effectiveness of the proposed remediation method on trial mining (field leach trial) is/has been required before permitting of full-scale operations is finalized
- Regardless of a passive or active approach:
  - Monitoring is required, perhaps in the long-term, to establish that sufficient forced/natural attenuation is occurring in a reasonable time scale and thus to give assurance that the desired or required **outcome** will be reliably achieved
  - All production wells and operational monitoring wells not required for on-going monitoring should be appropriately decommissioned at the end of mining (or progressively) to avoid the possibility of cross-aquifer contamination

Above-ground Remediation

The emphasis on remediation of ISL mines is often centred on the requirements of groundwater remediation, be that active or passive, above ground components and disturbance of ISL mines also require final remediation appropriate to the following land use and local regulations.



Beverley U mine: Photos P. Woods

Outlook for Uranium ISL

- Passed the 50% mark of annual world U production in 2014/15, +/- 50% since (equivalent to about 30,000 t/yr)
- Likely to remain the dominant U mining method for the next few years at least
- Longer term its relative contribution may decline somewhat
- Groundwater remediation (active or monitored natural attenuation) remains an important aspect
- Past pollution incidents still affect its acceptance

Summary and Conclusions

- ISL mining of uranium is currently the dominant production method
- This dominance is likely to continue over the next few years at least
- Ongoing improvements to the technique will be required to keep this place
- Safety, societal aspects, environmental and radiation protection and successful progressive and final rehabilitation will continue to be vital

Acknowledgement and Disclaimer

- Although this presentation is based closely on the official IAEA report, the choice of themes to emphasize, the summarizing of the salient text, addition of some additional material and choice of references remain the responsibility of the authors
- The permission of IAEA management to present this talk is appreciated
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IAEA headquarters, Vienna, Austria. Photo P. Woods