Feasibility through mining to closure: balancing the realities and expectations of uranium mining, and application to other commodities

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Part 1

- The IAEA’s work in uranium mining, and some useful publications

Photo: P. Woods
IAEA Support to (Uranium) Mining

Department of Nuclear Energy

Nuclear Fuel Cycle and Waste Technology

Waste Technology

Nuclear Fuel Cycle and Materials

Department of Safety and Security

Radiation, Transport and Waste Safety

Waste and Environmental Safety

Department of Technical Cooperation

Also aspects from the Dept. of Safeguards and Dept. of Nuclear Sciences & Applications, and the Office of Legal Affairs

Photo: P. Woods
IAEA Sub-programme on Uranium (Department of Nuclear Energy)

- Assessment of uranium resources, production and demand
  - NEA/IAEA Red Book
  - Database of uranium deposits
  - Standardization of resource classification (joint work with UNFC-2009)
  - Report series “Uranium geology, exploration, resources, production and related activities” in regions (6 volumes, final stages of preparation)

- Supporting good practices in the uranium production cycle
  - Uranium Production Site Appraisal Team
  - Optimization of mining technologies
  - Development of low grade ores
  - Unconventional resources – esp. phosphates
  - Thorium resources (e.g. by-product of REE)
  - Support training activities

- Technical Cooperation activities
  - Recent years: 18 national projects, 2 regional projects & an inter-regional project

Photo: H. Tulsidas, Tanzania, UPSAT 2013
Our unofficial motto:

To collect and share knowledge of uranium resources and support the development of a sustainable uranium production cycle in Member States.
Uranium Resources

• With NEA; RED BOOKs since 1965

• Uranium **YEAR**: Resources, Production and Demand

• Sources: governmental reports, secretariat reports and estimates

• Latest released NEA Nov. 2016
15 countries represent approx. 95% of total world U resources

1. Australia (Producer 3)
2. Kazakhstan (Producer 1)
3. Russian Federation (Producer 6)
4. Canada (Producer 2)

Note: numbers in blue are nation’s rank in world resources, those in red are the nation’s rank in world production.

*Identified Resources at <USD130 kg/U as of January 1, 2015

P. Woods 2017-04-24
Uranium Resources Production and Demand - Red Book

*Key messages in recent editions:*

Resources more than adequate to meet high case demand scenarios

Investment and expertise required to bring resources into production*

Production costs increasing*

Long lead times owing to regulatory requirements and public resistance*

P.S.

• If you downloaded the Red Book 2016 prior to April 2016, please revisit the site and download again for the revised official version

*Contributing to potential supply challenges over next 5-10 years*
Best Practices (general U mining - 1)

- IAEA 2009 Establishment of Uranium Mining and Processing Operations in the Context of Sustainable Development

- Includes case studies from Australia (Mary Kathleen, Nabarlek, Ranger), France, Canada, USA (Alaska), Niger, former Eastern Block/USSR, Germany (Wismut), Hungary (Mecsek)
Best Practices (general U mining - 2)

• IAEA 2010 Best Practice in Environmental Management of Uranium Mining
  • Includes proceedings of IAEA Technical Meeting held in Saskatoon, Canada, 22-25 June 2004
UMREG

Uranium Mining and Remediation Exchange Group

Selected Papers 1995–2007

Prospecting
Remediation
Decommissioning
Transport
Processing and Production
Mining

STEWARDSHIP

Exploration
Feasibility
Evaluation
Development of Production Facility

STI PUB 1524

UMREG

- In various forms, now running for over 20 years
- Official IAEA event since 2012 (Vienna)
- 2013 Czech Republic
- 2014 & 15 Germany
- 2016 USA
- 2017 France (to be formalised)
- Selected papers published 2011 – downloadable
- New volume of selected papers 2011-2015 in preparation (out 2017, all being well)
- Proceedings 2016 meeting in preparation (out 2017/18)
International Symposium on
Uranium Raw Material for the Nuclear Fuel Cycle:
Exploration, Mining, Production, Supply and Demand, Economics and Environmental Issues
23–27 June 2014
Vienna, Austria

URAM 2014

Proceedings for 2005 (STI/PUB/1259) and 2009 (TECDOC-1739) are downloadable

2014 Sessions on:
- Uranium markets
- Uranium geology and resources
- Uranium deposit evaluation
- Advances in exploration
- ISL and other U mining & processing
- Unconventional U resources, Th
- Health, safety and environment
- Social licensing, education
- Proceedings for 2014 in progress; abstracts & most presentations downloadable

Go to www.iaea.org and search for URAM 2014

Next one: 25-29 June 2018
Guidance for other mining commodities

As well as reports concentrating on uranium mining and milling, the Agency also publishes high-level standards for radiation protection in all industries, and specific guides for other mining in the Safety Reports Series (SRS):

- Radiation Protection and NORM Residue Management in the
  - Rare Earths from Thorium Containing Minerals (SRS 68)
  - Titanium Dioxide and Related Industries (SRS 76)
  - Phosphate Industry (SRS 78)
Safety Standards Series
(examples)

IAEA Safety Standards
for protecting people and the environment

Fundamental Safety Principles

Occupational Radiation Protection in the Mining and Processing of Raw Materials

Management of Radioactive Waste from the Mining and Milling of Ores

Safety Fundamentals
No. SF-1

SAFETY GUIDE
No. RS-G-1.6

SAFETY GUIDE
No. WS-G-1.2

IAEA
International Atomic Energy Agency
Safety Reports Series (examples)

Radiation Protection and NORM Residue Management in the Production of Rare Earths from Thorium Containing Minerals

Monitoring and Surveillance of Residues from the Mining and Milling of Uranium and Thorium

IAEA International Atomic Energy Agency
Other reviews


  - In general the 2011 review was positive
  - Several recommendations were made
  - This follow-up mission in 2014 showed good progress in the implementation of those recommendations
New uranium report

- In Situ Leach Uranium Mining: An Overview of Operations
- IAEA Nuclear Energy Series No. NF-T-1.4, Vienna, Austria, November 2016
Everyone’s objective should be safe and efficient mining, with social benefits something like this; a mine creating jobs and working with its community (left).

With a worthwhile end use in sight, e.g. a remediated uranium mine used for a raising cattle and fishing (right) (photos: P. Woods)
and to minimize on-going legacies and water treatment

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

Photos P. Woods Aug. 2013
Above: Straz main treatment plant; right: regional treatment plant, former satellite mine to Rozna mine
Not forgetting South Australia

- Brukunga former pyrite mine, Adelaide Hills
  – Water treatment needed for decades

The neutralisation process occurs in a series of 3 mixing tanks, which provides sufficient retention time for completion of the chemical reactions.
Part 2

• Reflections on feasibility studies, stakeholders, environmental protection and approvals

• Remembering that without a suitably well known orebody, viable technology of extraction, support infrastructure and access to markets, there can be no mine!
Practical and mining-aware enviros and social liaison folks

+ Environmentally and socially aware mining technologists, accountants and managers

= Better outcomes for a mining project

* This and some of the next few slides were first presented at the ALTA metallurgical conference in 2015
So why consider enviro and social?

- Bougainville Copper Mine
  - Opened 1969 whilst PNG was an Australian colony
  - Very financially important for PNG post independence 1975
  - ? Local community not getting enough benefits?
  - ? Bad environmental practices?
  - Closed by armed conflict 1989
  - Still negotiating a reopening 2015, 16, 17…

Photo source: WWW
‘FUD’ – Fear, Uncertainty, Doubt – easy to raise, harder to counter

Source: after Fetwadjieff 2010
Example of a potential mine blocked due to social issues

- Koongarra, Australia
  - Discovered 1970
  - Stopped by political intervention in early 1980s after $AU 100 million spent* (more spent since)
  - Udepo information:
    - Koongarra 1: 10 000 - 25 000 tU, 0.50 – 1.0 %
    - Koongarra 2: 1 000 - 2 500 tU, 0.20 – 0.50 %
  - WNA: 14 540 t @ 0.8% as U₃O₈
  - Aboriginal approval initially obtained, later withheld
  - 2013 Mining rights cancelled and area incorporated into Kakadu National Park and World Heritage Area

* Reynolds, E 1984 ‘Koongarra – the rolled by years and costs’ The AusIMM Conf. Darwin, NT, Australia, August 1984, pp73-83
Koongarra now National Park

“A long battle for protection of the sacred Koongarra area near Kakadu was today won, when traditional owner Jeffrey Lee watched as Federal Parliament moved to include it in Kakadu National Park.” 6 February 2013

Above:  
http://www.abc.net.au/local/stories/2013/02/06/3684748.htm

Right: photo and quote:  
http://australianmap.net/koongarra/

"I could be a rich man today. I could be a rich man. Billions of dollars... You know, you can offer me anything, but my land is a cultural land."

Jeffrey Lee, Djok Senior Traditional Owner
Useful international and national guidance is available

- International Council on Mining and Metals (ICMM: www.icmm.com)
- World Nuclear Association http://www.world-nuclear.org/
- The Uranium Institute Namibia (now Namibian Uranium Association)
  - HERSS Standards (version 2, 2012)
  - Standard of Good Practice for Health, Environment and Radiation Safety and Security
  - http://www.namibianuranium.org/
Some Australian guidance examples:

- Australian Government

- South Australian Government has issued its own guides, as have some other Australian states
Some national guidance examples:

- (former) Australian Uranium Association
  - Code of Practice for members (version 2, 2012)
    - in the context of the ICMM sustainable development framework and principles
    - defines principles of behaviour and standards of best practice to guide improvements in performance in the Australian uranium industry
  - Annual surveys of members’ performance against the code were published
  - Best practice guidelines for uranium explorers were also published
Often more general guidelines apply

- e.g. Canada
  - Environmental Code of Practice for Metal Mines
  - Includes legal requirements, but guidance (recommendations) is also included
  - Includes reference to IAEA docs (including one shown earlier)
Conclusion: common themes in international/national guidance

- Consider environmental and social aspect from the earliest exploration and planning stages
- Involve the government and the public, especially people living nearby
- A clear, fair and transparent regulatory environment is necessary
- Consider local and international general and specific guidelines and regulations
- Always consider the local and national circumstances of each project.
- Consider desired outcomes and not just regulated actions or standards
- From the beginning properly plan, account for and finance mine closure
- Do progressive rehabilitation if at all possible, and use its results to improve rehabilitation practices
Part 3

• Exploration data – collect a bit more information, save big in the next stages
Why this ambitious claim? Exploration is part of the big picture

Uranium Production Cycle

- Prospecting
- Exploration
- Feasibility
- Development
- Stewardship
- Processing & Production
- Mining
- Transport
- Decommissioning
- Remediation

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In reality: allow for interruptions?

Very many deposits

Many deposits!

Care-and-Maintenance e.g. Kayelekera (Malawi), Honeymoon (Australia)

some deposits, e.g. Trekkopje (Namibia), Imouraren (Niger)
Why that ambitious claim?

• Information on geometallurgy, environmental geology and hydrogeology can save time and expensive dead-end investigations if you have found something that is worth developing

• Baseline environmental and social information is best done over a period of 2 or more years, ideally more
  – Starting early can give a proper idea of variability of rainfall, other climate data, vegetation, water quality…
Environmental baseline data

- Simple things
  - Photograph points
  - Records of what housing/farming/pastoral activity is underway in the district
- For more advanced exploration projects with a camp
  - Rainfall records, or better an automatic weather station
  - Desktop fauna/flora/groundwater/surface water studies and initial measurements
Environmental baseline data (2)

- Long local rainfall records allow adjustments to be made to runoff calculations and therefore design of drainage, creek diversions, roads, water dams etc.
  - The cost of over-sizing water management structures can be large
  - The cost of fixing under-sized water management structures is worse; it can lead to production interruptions (roads cut by floods etc), environmental spills or even project closure

- If flood protection is very important, you may need to start creek/river flow measurements early

- If the only baseline environmental data is done late, it may be very unrepresentative
  - If you measure vegetation in an unusually wet year as baseline, later declines of vegetation or fauna may be unfairly blamed on you
Stage 1 Literature Review

• A thorough search for existing environmental information should be made
  – Maps; e.g. topography, geology, soil, population, land use, hydrogeology, infrastructure (as they may exist)
  – Aerial/satellite photographs
  – Published and grey literature
  – Technical reports
  – Data bases, e.g. climate, groundwater, flora, fauna
  – Land ownership
Stage 2 During Exploration (1)

- Climatic data
  - Rainfall, temperature
- Stakeholder liaison
  - Landholders, land users
  - National, state, local governments
  - Civil society (e.g. progress associations, environmental groups, business groups)
Stage 2 During Exploration (2)

- Non-target mineralogy
  - Sulphides, potentially toxic elements (e.g. arsenic, heavy metals)

- Groundwater baseline
  - Existing wells (e.g. pastoral, village water supply)
  - Water levels, water quality
  - Exploration camp wells

Photo: P. Woods, Heathgate Resources
Stage 2 During Exploration (3)

- Sometimes more formal environmental studies are required or advisable
  - Flora/Fauna
  - Radiation baseline, especially dust
  - Conventional dust

Photo: Rossing South, now Husab, Namibia; Extract Resources Limited
What you are trying to avoid; example, Rum Jungle U-Cu mine, Australia

- Mined 1954-1971, mostly U and Cu
- Main pollutants: acidity, Cu, Zn, Mn
- First government restoration in 1983-86 – problem improved but not solved
- Another restoration starting now following deterioration of the performance of the original scheme
Help out the metallurgists…

• Talk to one early!
• Be aware of interfering minerals;
  – Carbonates; interfere with acid leaching circuits
    • e.g. calcite worse than dolomite worse than siderite
  – Lignite, sulfides; compete for oxidizing agents
• Uranium mineralogy
  – Easy to acid leach; pitchblende/uraninite, coffinite
  – Hard to leach; brannerite, monazite
  – Note which secondary minerals, if present
Processing challenge due to mineralogy

- Gelling at Olympic Dam
- Formation of silica into polymers – gel
- Mainly due to changes in chlorite content of ore

Source: Ehrig 2013, “‘Gelling’: An operational challenge due to mineralogy’, 10th Annual SA Exploration and Mining Conference, South Australia, 28 Nov. 2013
Uranium minerals: Autunite & Torbernite

• Pretty, but others are usually more important even if boring…
Help out the water supply people…

• Talk to one early! Probably a hydrogeologist or a water supply engineer

• Have an idea where water might come from
  – Where do the local farmers, pastoralists get their water?
  – If you drill and have open holes, measure and record groundwater levels
  – If drilling with air, record any water made and from what depth
  – Look for fracturing that could be water bearing
Basic hydrogeological info is helpful

Pastoral water supplies, near Beverley, Australia

Photos: P. Woods
Help out for ISL planning…

• Talk to a relevant hydrogeologist or experienced ISL geologist/engineer

• Take notes on sand/sandstone that will be relevant
  – This can include sedimentological features like sorting (well-sorted = more permeable = good)
  – Look out for and include information on layering
  – Look out for location of mineralization
    • Best as ‘crusts’ on sand grains
    • Worst when in fined grained, and lignitic/pyritic sediment

P. Woods 2017-07 AusIMM
Logging is useful for more than geology

Diamond core, Argentina; drill cuttings, ISL mine, Texas, USA

Photos: left L. Lopez, right P. Woods
To summarize

• Remember we are all part of the mineral production cycle
• The chances may be small at the beginning, but really you are hoping to find something that is mined
• You don’t have to be an expert, but involve other expertise from later stages
• Happy exploring!
Acknowledgements & Disclaimer

• Although this much of this presentation is based closely on the official IAEA reports, the choice of themes to emphasize, additional non-IAEA material and choice of references remain the responsibility of the author.

• The permission of IAEA management to present this talk is appreciated.

• Always refer to the IAEA website and formal IAEA publications for official information and statements.

• Some slides were taken and adapted from a talk by IAEA colleague Adrienne Hanly.
Thank you for your attention

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and with thanks to many colleagues

Photo: P. Woods Jan. 2017
Further Reading - General


Further Reading – NEFW Technical Meetings and other Departments (small selection only)


• For a fuller list, see https://www.iaea.org/OurWork/ST/NE/NEFW/Technical-Areas/NFC/uranium-production-cycle_technical_meetings.html

Other Departments:

• For Safety Standards, Guides and Reports, see https://www-ns.iaea.org/standards/