Uranium Mining: Australia and Globally

fact sheet **06**

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Ranger Uranium Mine, Northern Territory, Australia: AAP Image/Mayu Kanamor

Uranium mining results in an environmental waste legacy.

Significant resources are required, including energy, water and industrial chemicals.

This Fact Sheet covers the start of the nuclear industry chain – uranium mining. It aims to present a concise overview of the nature of uranium, its mining and milling, and the numerous environmental and radiological aspects associated with this heavy industrial endeavour. It is clear that uranium is a finite resource and that the environmental costs associated with mining are significant and must be taken into account in any truthful analysis of the nuclear debate.

Common Questions:

1. What is uranium and how is it mined?
2. Is uranium mining like any other mining?
3. Are there sufficient uranium resources for the future?
4. What are the environmental impacts of uranium mining?
5. How much radioactive waste does uranium mining produce?
6. What are the radioactivity releases from uranium mining?
7. Can uranium mines be operated safely?
8. Can uranium mines be satisfactorily rehabilitated?

What is Uranium and How is it Mined?

Uranium is the heaviest, naturally occurring element. It consists of two principal isotopes – uranium-238 (^{238}U) with 238 neutrons in its nucleus, and uranium-235 (^{235}U) with 235 neutrons. The ^{235}U isotope is the desired isotope for nuclear reactors or nuclear weapons due to its ability to fission or split apart and release vast quantities of energy in the process. Natural uranium consists of 99.3% ^{238}U and about 0.7% ^{235}U. Uranium is unstable – it decays into slightly lighter elements, which are also unstable and further decay. The process of decay releases energy and a small atomic particle, and is known as radioactivity. There are two principal types of radioactive decay – alpha decay, the release of a charged helium atom, and beta decay, the release of an electron. This decay chain progresses through until a stable isotope is achieved (i.e. lead-206 or ^{206}Pb from ^{238}U and ^{207}Pb from ^{235}U). The rate at which an isotope decays is a characteristic of that isotope, and the time taken for 50% of an isotope to decay is known as its 'half-life'. The various decay products from uranium have half-lives ranging from fractions of a second to billions of years, shown in Table 1.

As uranium is mostly present in oxide form, it is commonly reported as either uranium (U) or its oxide 'U_3O_8'. Average concentrations of uranium in typical soils and rocks are about 3 mg/kg U_3O_8 or parts per million U_3O_8 (ie. about 3 grams per tonne). This background uranium is partly responsible for natural background radiation. In order to mine uranium economically using existing technology, this concentration has to reach at least 300 mg/kg or 0.03% U_3O_8, with most uranium mines historically ranging between 0.1 to 0.5% U_3O_8. Due to uranium's variable chemistry, it can be concentrated to mineable ore grades and deposits by numerous geologic processes. The most common types of mineable economic uranium ores are found in sandstone deposits, unconformity deposits, breccia complex deposits, intrusive deposits, metamorhpic deposits and surficial deposits.

Uranium is mined using traditional techniques such as open cut or underground mining, but sandstone deposits can also be mined by 'in situ leaching' (also known as solution mining).

Once the ore is mined it is finely ground and the uranium is chemically extracted through conventional processes involving leaching with acid or alkali, concentration and then purification to uranium oxide. Acid leaching is the most common. An oxidising chemical is commonly also used, such as pyrolusite (MnO_2) or hydrogen peroxide (H_2O_2), to ensure the leaching is rapid. For in situ leaching, the acid or alkali is injected directly into the ore zone and pumped back to the surface (no ore is excavated). After leaching from the ore, the uranium is further concentrated using solvent extraction or ion exchange, followed by chemical precipitation to an impure oxide using ammonia (this product is 'yellowcake'). Finally, the yellowcake is heated at high temperature to remove the ammonia and leave relatively pure uranium oxide (>97% U_3O_8).

Is Uranium Mining Like Any Other Mining?

Uranium ore is significantly radioactive – a property that is very uncommon across the mining industry. There are some other mineral deposits that also contain elevated uranium or thorium (also radioactive), however these are generally very few. A uranium ore deposit may have outcrops at the surface, presenting a major localised radiological risk, although more commonly uranium deposits are not visible at the surface and hence have negligible radiological risk. The geologic structure that holds the uranium is relatively stable. The process of mining and milling uranium ore involves severe disturbance to this natural equilibrium, especially as crystalline rocks are broken up during mining, ground for milling and aggressively chemically treated to liberate the uranium. An ore grade of 0.3% U_3O_8 means that 99.7% of the ore is left as solid waste, known as tailings (the minor loss of uranium is easily made up by the amount of chemicals added during leaching). Uranium mill tailings retain about 85% of the original radioactivity of the ore, and must be managed so as to minimise releases of radioactive decay products such as radium and radon as well as heavy metals (eg. arsenic, copper, lead).

The requirement to manage the radioactive tailings and all other solid wastes to minimise both long-term environmental as well as radiological releases and impacts makes uranium mining fundamentally different to other types of mining.

Are there sufficient uranium resources for the future?

Uranium, like all other mineral commodities, needs to be present in both sufficient concentration and contained uranium to be economic to mine. The number of deposits which meet these criteria are relatively uncommon, and they require extensive mineral exploration to find. There have been two principal phases of exploration leading to significant economic deposits being discovered. The first period was the Cold War when uranium was highly sought after for the nuclear weapons programs of the 1950's and 1960's. Globally, most uranium in this period was found in northern Ontario in Canada and in the mid-west states of the United States, with only minor deposits discovered in Australia (though they were politically critical in Australia's nuclear posture). The second period of uranium exploration stemmed from the perception that commercial nuclear power was becoming a reality in the late 1960's, and that then known resources of uranium were insufficient for long-term supply. Exploration around the world led to major success in the early 1970's in discovering rich new provinces with several high grade and large deposits, especially in Australia and northern Saskatchewan in Canada. Although some new deposits have been discovered in the past decade, very few have proved as large or as rich in grade as those found in the 1970's.

The extent of known resources depends critically on exploration and the market price of uranium, with uranium resources often presented in terms of predicted cost of mining. As shown in Figure 1, world and Australian economic resources appear to have plateaued, although the ore grades of these resources are declining over time (data not shown). This leads to major issues in terms of the environmental costs of extraction of any future mining of these lower grade deposits. Uranium is clearly a finite resource, with exploration having to look deeper for new deposits. It will be increasingly constrained in the future by the environmental costs of mining lower grade ores.

What are the environmental impacts of uranium mining?

The environmental impacts of uranium mining include the traditional impacts associated with gold or copper mining, as well as additional radiological impacts. Depending on the type of deposit and method of mining, the environmental impacts are associated with solid waste management, water management, and chemicals and emissions from milling.

In open cut mining large quantities of waste rock are excavated to access the ore, with much of this waste rock also containing low grade, uneconomic quantities of uranium. Additionally, this waste rock may also contain sulphide minerals such as pyrite. When undisturbed in situ this rock is stable. However, the process of mining increases the cracks present and allows water and oxygen to diffuse into the waste. The oxygen and water reacts with the sulphide to produce sulphuric acid. This in turn dissolves much of the heavy metals and radionuclides present in the waste, allowing it to leach out of the rock into the surrounding environment. This leachate, known as acid mine drainage (AMD), is extremely toxic to aquatic ecosystems and will cause major, long-lasting environmental impacts. AMD is a major problem in the mining of many metals, but presents an additional problem when combined with uranium mining. Infamous sites where environmental impacts from AMD have been extensive include Rum Jungle, near Darwin in Australia, as well as the Elliot Lake district in northern Ontario, Canada.

The long-term management of uranium mill tailings present a major environmental challenge. Given the tailings contain most of the original radioactivity of the ore (i.e. the decay products), they must be isolated from the environment for periods of at least tens of thousands of years – a time scale which is beyond collective human experience and certainly challenges engineering approaches for waste containment.

Until the 1970's uranium mill tailings were commonly poorly managed. At Rum Jungle, tailings (and liquid wastes from the mill) were dumped onto the adjacent floodplain for several years – eroding through every wet season into the local Finniss River. A brief period of disposing of tailings into former open cuts was then trialled. Combined with toxic AMD leachates, the poor tailings and water management at Rum Jungle led to severe environmental impacts covering 100 km2 of the Finniss River ecosystem. At Grand Junction in Colorado the tailings were at one time even actively sourced for use in building construction materials. The very low-grade tailings from the Radium Hill mine in South Australia were used as ballast for railway line and even road construction.

Since the late 1970's, in Australia at least, more stringent requirements have been placed on solid waste and water management at uranium mines. At Ranger, all tailings will be required to be emplaced within former open cuts and all waste rock re-contoured to a landform which is intended to be stable. For Olympic Dam, however, the present planning is for all tailings to remain above ground and then covered with engineered soils to minimise erosion, infiltration and radiological releases.

Recent analyses have examined the energy and water costs and greenhouse emissions associated with uranium production. Energy is measured in Joules, and a GJ is one thousand million Joules. (About 1GJ of heat would be produced by 500 typical electric radiator bars operating for an hour.) The analyses show that the energy cost of extracting uranium is between 170 to 350 GJ per tonne of U_3O_8, with higher values from lower grade ores, while for water it takes between 46,000 to 2,900 litres/t U3O8 (eg at Beverley, an acid leach mine, consumes an average 7.7 million litres of water per tonne of U_3O_8). The corresponding greenhouse emissions of carbon dioxide ranges from 8.5 to 51 t CO2/t U_3O_8. These environmental costs are particularly sensitive to ore grade, with higher values from lower grade ores.

How much radioactive waste does uranium mining produce?

The radioactive nature of uranium means that any mining leads to the production of significant quantities of radioactive wastes – principally waste rock and tailings. The extent of waste will depend on the specifics of a particular deposit and mine plan, but in general open cut mining produces significantly more waste than underground mining. By December 2005 in Australia, on average, each tonne of uranium extracted has led to the production of 848 tonnes of mill tailings and 1,152 tonnes of combined low-grade ore and waste rock (excluding in situ leach production). The total quantity of tailings is about 128 million tonnes (grading about 0.03% U3O8) with about 175 million tonnes of combined low-grade ore and waste rock. In comparison to the volumes of radioactive waste in the nuclear fuel chain, the largest quantity is easily produced in the mining and milling of uranium.

What are the radioactivity releases from uranium mining?

The releases of radioactivity from uranium mining are sourced from tailings, low-grade ore and, to a lesser extent water management. The principal release is that of radon – a noble gas that is a radioactive decay product of uranium. Radon has a high rate of radioactivity per mass, and is implicated in lung cancers in long-term health studies of former uranium mineworkers.

Can uranium mines be operated safely?

The most recent experience of Australia's operating uranium mines demonstrates the challenges involved in uranium mining, which are distinct and unique. There have been numerous incidents at the now closed Nabarlek mine and the operating Ranger, Olympic Dam and Beverley projects. The most common examples include mismanagement of water, sometimes leading to unauthorised releases to adjacent creeks, significant risks to mine/mill workers, waste rock leaching, and ongoing seepage impacts from tailings. Some relatively recent examples include:

Ranger:

- despite being expected to operate under a "no-release" water management system, incidents involving mis-placed low grade ores or failures in water control bunds have led on numerous occasions to contaminated runoff waters being leaked into adjacent creeks (especially Corridoor Creek, a tributary of Magela Creek).
- in early 2004 incorrect plumbing saw the process water circuit being connected to the potable drinking water circuit – leading to rapid and significant toxic process water being mixed with drinking water, and much of the Ranger workforce being potentially exposed to both acute chemical and radiological exposure.

Olympic Dam:

- after operating for nearly a decade, a major ongoing leak from the tailings dam was revealed, amounting to the loss of billions of litres of tailings water to groundwater.
- in March 1999, and again October 2001, major explosions and fires caused substantive damage to the mill and smelter complexes, including major releases of noxious fumes – though the extent of radiological releases remains highly contentious, the fact that the uranium solvent extraction circuit in the 2001 incident was on fire raises serious concerns about how these incidents are handled by current regulators.

Beverley:

- numerous spills and leaks from pipelines have occurred.

Nabarlek (now closed):

- due to the need to reduce the inventory of contaminated mine site waters, evaporation pond water was irrigated over an area adjacent to the mine/mill and led to significant tree deaths and lasting impacts on water quality in the adjacent creek which have taken nearly two decades to flush through.

Can uranium mines be satisfactorily rehabilitated?

The experience of rehabilitating uranium mines to date in Australia is questionable. The first generation of uranium mines from the Cold War, namely Rum Jungle, Radium Hill, Mary Kathleen and the South Alligator group of mines, all still present environmental and radiological management problems and require constant vigilence and maintenance. Examples include:

- **Rum Jungle** – despite extensive remediation/rehabilitation works in the early 1980's, including excavating remnant tailings and disposal into former pits, re-contouring and engineering soil covers over low grade ore and waste rock dumps, acid mine drainage continues to pollute the Finniss River, and the complete site still urgently requires more remediation/rehabilitation works.
- **Radium Hill** – after being abandoned in early 1962, minimal earth works were undertaken in the early 1980's, mainly just engineering soil covers over the tailings piles – erosion is a continual problem and tailings requires ongoing maintenance.
- **Mary Kathleen** – operating in both the Cold War phase of the late 1950's to mid-1960's as well as again in the commercial era of the late 1970's, the mid-1980's rehabilitation of the mine won an engineering excellence award for its perceived quality – despite internal concerns by the regulators about potential for long-term seepage from the tailings dam. Recent field studies in the late 1990's have validated this concern and shown ongoing seepage of saline, metal and radionuclide rich waters from the tailings dam – well above the quantities predicted at the time of rehabilitation – impacting on the local creek.

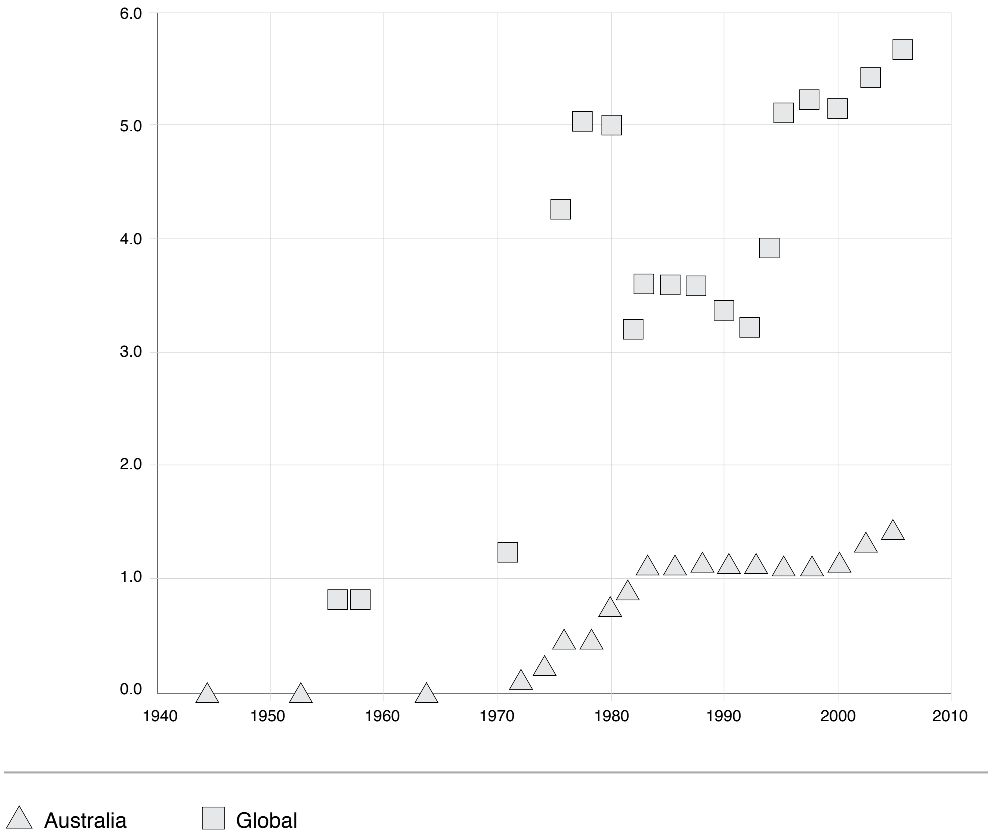
Overall, the experience to date with uranium mining does not give rise to any sufficient degree of confidence, as past sites – even after significant rehabilitation works – are still showing problems with erosion and seepage and ongoing impacts on water quality.

Table 1 – Uranium Radioactive Decay Chain and Half-Lives

Isotope	Decay and Half-Life		Isotope	Decay and Half-Life	
^{238}U	α	4.51 billion y	^{206}Pb	–	stable
^{234}Th	β	24.1 d	^{235}U	α, γ	710 million y
^{234}Pa	β, γ	1.17 m	^{231}Th	β	25.5 d
^{234}U	α, γ	247,000 y	^{231}Pa	α, γ	32,500 y
^{230}Th	α, γ	75,000 y	^{227}Ac	β	21.6 y
^{226}Ra	α, γ	1,600 y	^{227}Th	α, γ	18.5 d
^{222}Rn	α	3.82 d	^{223}Ra	α, γ	11.4 d
^{218}Po	α	3.05 m	^{219}Rn	α, γ	4.01 s
^{214}Pb	β, γ	26.8 m	^{215}Po	α	0.0018 s
^{214}Bi	β, γ	19.7 m	^{211}Pb	β, γ	36.1 m
^{214}Po	α, γ	164 µs	^{211}Bi	α, γ	129.0 s
^{210}Pb	β, γ	22.3 y	^{207}Tl	β	286.6 s
^{210}Bi	β	5.01 d	^{207}Pb	–	stable
^{210}Po	α	138 d			

Notes : α - alpha, β - beta & γ - gamma decay.

Figure 1 – Global and Australian Economic Uranium Resources Over Time



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About our organisation:

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