The Specifics of Uranium Exploration in Remote Areas of Western Australia

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ABSTRACT

The uranium exploration activity in Western Australia has increased significantly in the last two years. Total currently identified uranium resources are in order of 100,000 tons of U_3O_8 and it is likely that more uranium deposits will be found in the State. The exploration activity is typically carried out in very remote locations in Western Australia and, frequently, on the land that is subject to the Australian Native Title Act (1993) – in the areas where the potential radiation exposure of the Traditional Land Owners has to be considered.

Aboriginal groups are an integral part of dynamic ecosystems, for whom to separate 'man' from 'nature' is a convention with little meaning when dealing with environmental impact, and this needs to be taken into account by uranium exploration companies.

Indigenous peoples' potential exposure to radiation as a result of uranium exploration cannot be modelled based on common assumptions. Indigenous people may be at a higher risk of radiation exposure at and around uranium exploration sites that may not have been adequately rehabilitated due to, for example:

- Travelling on dusty roads in open vehicles,
- Sitting on the ground, living and sleeping in temporary structures with earth floors,
- Lack of adequate washing facilities, eating local biota and cooking in the ground,
- Recreational activities (particularly by children).

The radiation protection regulations in Western Australia are complex and somewhat confusing as there are three State government departments administering different regulations that may be applicable to uranium exploration.

The paper discusses the specifics of required radiation monitoring and potential radiation exposure assessments in remote areas of Western Australia. The methods for the co-operation between exploration companies, government departments, and Traditional Owners to ensure safe and successful uranium exploration are also discussed.

Keywords: uranium, exploration, remote, Australia, Aboriginal

Introduction

The recent resurgence in uranium exploration is explained by the significant increase in the price of uranium on the world market [1 – 6], from under US$10/lb of uranium concentrate (historically called 'yellowcake') in the 1990-s to around US$50/lb in 2008; making the exploitation of low grade uranium deposits (at and below 0.05% uranium) viable. The recent change of Government in Western Australia has opened the way for uranium mining to commence in the State.

Detailed descriptions of uranium resources [1, 7] and current exploration [1] activities in Australia indicate that vast reserves of uranium are available to be recovered at a relatively low cost to mining companies.

The situation with uranium exploration in Australia in general was described at the technical meeting organised by the International Atomic Energy Agency (IAEA) in 2004 [8], where it was demonstrated that Australia showed the greatest disparity between exploration expenditures (3% of worldwide exploration expenditure) and relatively low-cost known resources (38%).

It was concluded at the time that "the question of why Australia has not attracted more exploration dollars may find its answer in politics and a well organized environmental community opposed to uranium mining" and that "the combination of uncertainty surrounding development of Jabiluka and the potential cloud hanging over uranium mining in Western Australia could partially explain the seeming disparity between exploration expenditures and low-cost known resources." [8]

In November 2008 new Premier of WA Colin Barnett announced the lifting of the ban on uranium mining in Western Australia. As the Information Circular from the WA Chamber of Minerals and Energy specified:
"…mining leases would be granted to cover all minerals, including uranium, unlocking tens of millions of dollars in royalties revenue, employment opportunities and allowing the state to play a greater role in the fight against climate change.
"Like other mining operations in the state, the mining of uranium will be subject to strict environmental, safety and security provisions including:

- meeting all the necessary international safeguards in relation to the safe and peaceful use of uranium resources,
- that environmental approvals are obtained in relation to the mining of uranium and the transport of uranium oxide, and
- ensuring a safe workplace for all employees involved in the mining and the transport of uranium oxide.

The Premier said these provisions were fair, balanced and in accord with international standards." [9]

There are numerous known uranium deposits in Western Australia [10] and current exploration activities would, most likely, lead to the discovery of other deposits.

There are several stages in the mineral exploration process:

1. The initial stage involves collection of new and evaluation of already available geological data that is gathered remotely with the help of satellite and/or aerial surveys.
2. The second stage may involve random sampling in selected areas and some investigative drilling. Typically, access to a particular site will be necessary and some ground disturbance (although relatively minor) would occur.
3. The third stage is typically a detailed exploration for the assessment of mineral deposit. This may result in a substantial ground disturbance due to drilling, development of new access tracks and also due to the presence of an exploration camp. From the radiation protection point of view this stage is the most significant and, therefore, requires additional attention.

Uranium exploration – health effects

It is expected that the exposure of workers involved in uranium exploration would be very low. As detailed in a document of the Department of Consumer and Employment Protection of WA, "recently at a major WA exploration site where hundreds of thousands of tonnes of uranium ore were moved that involved 44 workers, the doses ranged from 0 to 0.33 mSv. The highest dose of 0.33 mSv was received over 786 hours." [11] This value of worker's exposure is significantly lower than the limit of radiation exposure for members of general public. Even in a hypothetical case when the highest observed level of exposure is extrapolated for the complete working year (2000 hours), the value is expected to be below the public exposure limit of 1 mSv/year.

Two main pathways of radiation exposure that may be applicable for uranium exploration workers are exposure to external gamma radiation and the inhalation of radioactive dust.

When modern drilling methods are used in uranium exploration it is very unlikely that large amounts of dust will be generated. It is also unlikely that this dust will be dispersed by the wind far from the drilling site. Furthermore, the concentrations of uranium in the dust are typically relatively low and accidental inhalation of such dust for short periods of time (several hours) is very unlikely to result in a detriment to human health. In fact, the internal exposure to the potentially radioactive dust generated in uranium exploration for several hours would be, in most cases, very difficult to quantify.

It also appears unlikely that members of the public may be exposed to external gamma radiation in excess of the natural background during the normal course of exploration, unless they visit drilling sites and sample storage areas whilst the exploration takes place. In these cases the data obtained by the monitoring of workers can be used for the assessment of possible doses received by visitors.

It is, therefore, concluded that any potential measurable radiation exposure for members of the public may only be caused by an unsuccessful and/or partial rehabilitation of the drilling site, after the exploration activity ceases.

Uranium exploration – environmental impacts

Most members of the public that could be exposed to radiation associated with uranium exploration in remote areas of Western Australia are representatives of indigenous communities in the vicinity of a mining/exploration site. Therefore, it is of an utmost importance that not only occupational but also all possible environmental impacts of uranium exploration are identified by both mining exploration companies and regulatory authorities.

It has been recognised internationally that – "Aboriginal groups are in some countries an integral part of dynamic ecosystems, for whom to separate 'man' from 'nature' is a convention with little meaning when dealing with environmental impact. The native cultures stress 'seven generations' as a reference for accountability. Science and all forms of knowledge are useful and desirable, but human experience and wisdom accumulated through generations remain the basis for judgement." [12]

The current view of the International Commission on Radiological Protection (ICRP) is that "that the standards of environmental control needed to protect the general public would ensure that other species are not placed at risk." [13]

There is no clear international guidance as to how the radiological protection of the environment should be implemented, particularly in situations where humans are not present. Examples of these situations are deep sea water and extremely remote areas of Western Australia where a group of people may only 'pass through' once every 10-20 years, or so.
Other similar situation is the case where the distribution of radionuclides in the environment is such that the exposure to humans would be minimal, but other organisms in the environment could be considerably exposed.

In recent years there has been an extensive discussion and many scientific conferences and workshops were held on the issue [14 – 19]. A survey of environmental radiation protection in the law was also carried out [20].

An improvement in the system of radiation protection was clearly necessary and in 2003 ICRP issued special recommendations for assessing the impact of radiation on the environment [21].

When the clear principles of the radiation protection of non-human species will become available, it is expected that it will take a considerable amount of time for them to 'flow through' into the Australian legislative framework.

It appears, however, that a limited amount of monitoring of the effects of radiation on the environment is already being carried out at some uranium mining operations in Canada [22] and Australia [23].

The Annual Reports of the Office of the Supervising Scientist in Australia's Northern Territory detail, among other issues, the results of inspections of the sites where mineral exploration for uranium occurs. The inspection program involves representatives of the Office of the Supervising Scientist, the Northern Territory Department of Business, Industry and Resource Development and the Northern Land Council (acting on behalf of the Aboriginal Traditional Owners). Operational, recently completed and rehabilitated drill sites as well as various camp sites, water collection/pumping points, helicopter landing pads and roads associated with the campaigns were inspected. It was concluded that "…the level of environmental management performance generally being very good. There has been a significant improvement in the companies' environmental management over the past few years, such that the present standard is high." [23]

It is deemed essential that a similar system of inspections addressing environmental management at uranium exploration sites in Western Australia be established as soon as possible.

The decision in regard to the success of the environmental rehabilitation of a particular site should not be based on the mining company's reports alone, but confirmed by independent measurements and assessments, preferably by a government department or an independent specialist, or both.

From the theoretical point of view, the potential impacts of radiation on the non-human species are similar to the impacts on humans and a summary is presented below:

- Flora (plants):
  - External gamma-radiation;
  - Surface contamination (absorption of dust settling on leaves/ branches and radon);
  - Waterborne radioactivity (uptake of radionuclides via the root system).
- Fauna (animals and insects):
  - External gamma-radiation;
  - Airborne radioactivity (inhalation of dust and radon);
  - Waterborne radioactivity (ingestion of radionuclides);
  - Surface contamination (on direct contact with a contaminated material);
  - Ingestion of contaminated flora.
- Ground/soil/groundwater – subterranean organisms:
  - External gamma-radiation;
  - Waterborne radioactivity (ingestion of radionuclides).
- Surface water – aquatic organisms (flora):
  - Immersion – exposure to external gamma-radiation;
  - Uptake of radioactivity from both sediments (via roots) and water itself.
- Surface water – aquatic organisms (fauna):
  - Immersion – exposure to external gamma-radiation;
  - Ingestion of aquatic flora.
- Atmosphere (fauna):
  - Airborne radioactivity (inhalation of dust and radon);
  - Ingestion of contaminated flora and fauna.

Having particular regard to Aboriginal practices, the exposure to radiation may be a result of not only *direct* pathways of radiation exposure such as external gamma-radiation, inhalation of dust/radon, and ingestion of drinking water, but also several *indirect* ones, such as:

- Ingestion of contaminated flora (both surface and aquatic),
- Ingestion of contaminated fauna (both surface, air and aquatic),
- Incidental ingestion of dust and soil (particularly for children).

The number of pathways of radiation exposure that may be applicable (and therefore may need to be monitored) should be determined on a case-by-case basis, depending on the local environment, the scale of exploration operations, and on the life style and practices of a particular community.

As almost no processing of samples (chemical or otherwise), apart from occasional core cutting, usually takes place at uranium exploration sites, the most common case would be the monitoring of the following media:

- Ground/soil – external gamma radiation and, in some cases, radon emanation rates;
- Air – concentrations of radioactivity in airborne dust and, in some cases, concentrations of radon and its decay products;
- Water – concentrations of radionuclides (typically uranium-238 and radium-226) in surface and/or ground water.

In certain cases samples of local flora and fauna should also be collected for future reference and comparison.

The results of the ‘post-exploration’ monitoring should be compared with the data obtained prior to the exploration operations taking place – to assess if the levels of radioactivity in any of the measured media are elevated and, if they are, to what degree.

It is important to note that a broad monitoring program needs to be undertaken and all anomalies in radionuclides concentrations should be identified prior to the commencement of exploration activities. For example, it is possible that concentration of radium-226 in the ground water would be naturally elevated in areas of uranium mineralisation (in comparison with the ground water in areas adjacent to the exploration lease). If this anomaly is not identified during the pre-operational stage, it may be attributed to the exploration (or future mining) operations of a company and a costly remediation program may subsequently be required.

After all possible pathways of radiation exposure have been identified, a theoretical assessment of the radiation exposure to the members of the general public is carried out and results are compared with appropriate limits. It is expected that the result of this assessment will be used in the determination if a particular site is ‘contaminated’, as defined in the Western Australian Contaminated Sites Act 2003 [24], in accordance with the criteria described below, in part 5.

In the case of the uranium mining operation the monitoring of environmental media (particularly water and air) should be carried out at a frequency that will allow for the early identification of any unusual increases in concentrations of radionuclides. Whilst the environment may, to some degree, become affected – the exposures to the members of the general public would be significantly reduced or avoided all together through the use of such an ‘early warning system’.

Legislative framework in Western Australia

As in other countries, in Australia international recommendations and guidelines are considered by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), which develops Codes of Practice and Safety Guides relevant to Australian conditions.

The principal radiation protection document in Australia is the National Directory for Radiation Protection [25]. The principle of applying uniform radiation protection regulations throughout Australia is detailed in this document and is based on the decision of the Australian Health Ministers’ Conference (AHMC) that “agreed that upon consideration and approval of the provisions of the Directory, the regulatory elements of the Directory shall be adopted in each jurisdiction as soon as possible, using existing Commonwealth/State/Territory regulatory frameworks”. The first edition of the Directory, however, is not applicable to the mining and mineral processing industries.

The Australian Code of Practice for radiation protection in mining and mineral processing [26] has been developed and will form a part of the second edition of the National Directory that is expected to be published in the near future. This Code of Practice will be adopted into the Western Australian legislative framework: with the implementation of the second edition of the National Directory, or earlier – into both Radiation Safety Regulations [27, 28] administered by the Radiological Council, and into Mines Safety and Inspection Regulations [29] administered by the Department of Mines and Petroleum.

At mining and exploration sites the provisions of Part 16 – Radiation Safety of the Mines Safety and Inspection Regulations are the primary regulatory instrument. These regulations are supported by the set of guidelines detailing methods acceptable for the implementation of specific regulations.

Most of the guidelines were initially developed in early 1990-s and there was a clear need to review and update them to reflect contemporary industry practice, current scientific knowledge, new developments in monitoring methods and international best practice in radiation protection. The review of the radiation safety guidelines was carried out in 2006–2008 period as a joint initiative between the Department of Mines and Petroleum and the Chamber of Minerals and Energy of WA.

The new guidelines adopting the current national approach to radiation protection and radioactive waste management in mining [26] were published in 2008 [30, 31]. The suite of fourteen guidelines consists of the following documents:

1. Applying the system of radiation protection to mining operations
2. *Two guidelines describing radiation management plans:*
   2.1. Preparation of a radiation management plan – exploration
   2.2. Preparation of a radiation management plan – mining and processing
3. *Five ‘monitoring’ guidelines:*
   3.1. Pre-operational monitoring requirements
   3.2. Operational monitoring requirements
   3.3. Air monitoring strategies
   3.4. Airborne radioactivity sampling
   3.5. Measurement of particle size
4. *Three ‘control’ guidelines:*
   4.1. Dust control strategies
   4.2. Management of radioactive waste
   4.3. Transport

5. Radiation dose assessment
6. Reporting and notifying
7. Boswell – assessment and reporting database

These documents reflect the latest international best practice in radiation protection and are expected to form a foundation on which mining and exploration companies will base their radiation protection programs. As these guidelines were officially published prior to the change in the State Government policy in regard to the mining of uranium [9], they are currently undergoing a review to ensure that any additional relevant issues are addressed.

The most important guideline that must be considered in the management of radioactivity in the process of uranium exploration is the one describing the development of a radiation management plan for an exploration site. In addition to the part describing elements to be included in the plan and to the 'check list' it also contains:

- Description of applicable government regulations and codes of practice,
- Basic principles of radiation safety and limits of radiation exposure,
- Guidance for the essential monitoring program and types of required monitoring,
- Description of the control of radiation exposure in general and in regards to storage and handling of core and other mineral samples such as rock chips,
- Suggestions for the handling of potentially contaminated equipment, and
- Principles of environmental management.

The last point requires specific attention due to the applicability of the WA Contaminated Sites Act to mining exploration site, as described below.

Contaminated Sites Act and Regulations – Western Australia

In relation to a particular site, the Western Australian Contaminated Sites Act defines 'contaminated' as: having a substance present in or on that land, water or site at above background concentrations that presents, or has the potential to present, a risk of harm to human health, the environment or any environmental value [24].

The Western Australian Department of Environmental Conservation introduced the classification for all known or suspected contaminated sites [32] and the specific guideline was developed by the Radiological Council of Western Australia [33], which defines the sites as follows:

1. *Report not substantiated:* there is no information to indicate the presence of contamination on the site.
2. *Possibly contaminated – investigation required:* there are grounds to indicate the presence of contamination at the site, but more information is required to confirm or dismiss the possibility of contamination.
3. *Not contaminated – unrestricted use:* after the investigation, the site was found not to be contaminated. The mean dose to a member of the critical group of the members of the general public is below the dose constraint of 0.3 mSv/y.
4. *Contaminated – restricted use:* the site is contaminated but suitable for restricted uses (e.g. the site may be suitable for the industrial, but not the residential use; or the site may be suitable for any land use, but restrictions on excavation and/or ground water use may apply). The mean dose to a member of the critical group of the general public is above the dose constraint of 0.3 mSv/y, but below the annual limit for the radiation exposure of 1.0 mSv/y.
5. *Remediated for restricted use:* the site that was contaminated has been remediated so that it is suitable for restricted use. The mean dose to a member of the critical group of the general public is above the dose constraint of 0.3 mSv/y per year, but below the annual limit for the radiation exposure of 1.0 mSv/y.
6. *Contaminated – remediation required:* the site is contaminated and remediation is required to ensure it does not present a risk to human health, the environment or any environmental value. The mean dose to a member of the critical group of the general public is above the annual limit for the radiation exposure of 1.0 mSv/y. In some very rare cases the value at which remediation is necessary may be increased to 3.0 mSv/y.
7. *Decontaminated:* The site has been remediated, is suitable for all uses and does not pose a risk to the environment or any environmental value. The mean dose to a member of the critical group of the members of the general public is below the dose constraint of 0.3 mSv/y.

It is believed that the values selected in the guideline are appropriate:

- The highest possible value of exposure (3.0 mSv/year) under which environmental remediation of a site may not be necessary (naturally, only in extraordinary circumstances) is the same as the "the dose criterion for the designation of radioactively contaminated land", that is applicable in the United Kingdom [34].
- In typical situations, the level for the classification of the site as 'contaminated' is the same as the limit of radiation exposure for the members of the general public, 1.0 mSv/year.
- The dose constraint of 0.3 mSv/year is in line with current recommendations of the International Atomic Energy Agency: "For the unrestricted use of a site, it should be ensured… that the effective dose to a member of a critical group is kept below the dose constraint of 300 microSv in a year. For the restricted use of a site it should be ensured that, with restrictions in place, the effective dose should not exceed the dose constraint of 300 microSv in a year and that if the restrictions were to fail in the future the effective dose should not exceed 1 mSv in a year." [35]

In the practical application of these values (and having a particular regard to Aboriginal culture and practices) it may be necessary to carry out additional radiation protection studies, particularly in situations where the distribution of radionuclides in the environment is such that the exposure to humans would be minimal, but other organisms in the environment could be considerably exposed.

It will also be necessary to determine if all radionuclides in the uranium decay chain stay in secular equilibrium to confirm that different elements (such as radium-226 and lead-210) are not leaching into the ground water or concentrating in the food chain.

In the estimation of the level of potential radiation exposure the applicability of all possible pathways of radiation exposure listed above must be assessed and the exposure through those pathways identified as applicable – measured and assessed.

The paper is based on the report 'Uranium Exploration – Safety, Environmental, Social and Regulatory Considerations' [36], prepared by the author in February 2009.

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