RADIATION AND OCCUPATIONAL HYGIENE

IN THE MULGA ROCK PROJECT

REPORT TO ENERGY AND MINERALS AUSTRALIA LIMITED

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RADIATION ADVICE & SOLUTIONS PTY LTD

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1. INTRODUCTION

This report summarises the typical required radiation and occupational hygiene controls in mining and processing of ores containing uranium and base metals, as presented within the Mulga Rock Project.

This report foreshadows information that will be further developed for input into the Definitive Feasibility Study (DFS) and the Environmental Impact Statement (EIS), in which detailed predictions will be provided and control options will be developed which describe how all potential radiation doses, occupational hygiene hazards, and environmental impacts will be minimised.

2. RADIATION BASICS FOR URANIUM MINING

2.1 Dose Control Philosophy

Radiation dose control requirements in all Australian states follow the ARPANSA and ICRP philosophy, which is that all doses from regulatable activities or ‘practices’ must be:

- justified;
- optimised; and
- constrained or limited.

Justification is achieved by formal approval and licensing of the operation (whereby society justifies the ‘practice’).

Optimisation is achieved by management plans, which are intended to ensure doses are kept “As Low As Reasonably Achievable” (the ALARA principle).

Limitation is achieved by ensuring compliance with the limits, being the Annual Radiation Worker dose limit of 20mSv, and Annual Member of Public Limit of 1mSv.

It is to be noted that these limits are on doses which are project-originating, and thus above or in addition to, or incremental to, dose from natural background, and also exclude any dose arising from medical procedures (because natural radiation is not amenable to control by the company, and medical doses are separately justified).

2.2 Radiation Theory

Uranium and Thorium both break down to produce ‘daughter’ radioactive elements, or radionuclides, in a succession of nuclear transitions called the U and Th decay chains. During each transition, alpha (α), beta (β), or gamma (γ) radiation is emitted from the decaying atom. Each radionuclide decays with its own characteristic half-life, giving out radiations with their own specific energies.

Table 1 U-238 Decay Chain

Nuclide	Radiation	Energy (MeV)	Half-life
Uranium 238	α	4.2	4.5 billion years
Thorium 234	β γ	0.2 0.06, 0.09 (weak)	24 days
Protactinium 234 Uranium 234 Thorium 230	β α α	2.3 4.7 4.7	1.2 minutes 250,000 years 80,000 years
Radium 226	α γ	4.8 0.186 (weak)	1,600 years
Radon 222 (gas)	α	5.5	3.8 days
Polonium 218	α	6.0	3 minutes
Lead 214	β γ	0.7 0.3, 0.35	27 minutes
Bismuth 214	β γ	1.0, 1.5, 3.3 0.6, 1.1, 1.8	20 minutes
Polonium 214	α	7.7	160 microseconds
Lead 210	β γ	0.016 0.047 (weak)	22 years
Bismuth 210 Polonium 210 Lead 206	β α -	1.16 5.3	5 days 140 days infinite, lasts forever

Note: Main gamma emitter is Bismuth 214, main emission is at 609 keV

Bold nuclides above are the notorious 'radon daughters'. (These will not be a concern on the Mulga Rock Project).

α = doubly-ionized Helium atom, ejected from nucleus at very high speed

β = electron emitted from nucleus at high speed (n → p + e)

γ = gamma ray

3. DESIGN CONSIDERATIONS

3.1 Radiation Dose Delivery Pathways for Mine and Plant Workers

Doses to workers and to members of the public, and their controls, are discussed by considering the different potential "dose delivery pathways" one by one, and then describing their likely significance (or otherwise) and the control options available.

In principle, in the mining and processing of radioactive ores; there are four dose delivery pathways by which people can receive radiation doses:

(i) by gamma 'shine' or direct irradiation from large masses of mineralised material or tailings material;

(ii) by inhalation of long-lived alpha-emitting radionuclides (U, Th, Ra, Po) in airborne mineralised material dust, process dust, product dust, or tailings dust;

(iii) by inhalation of short-lived radon decay products formed from radon in the air;

(iv) by ingestion of radionuclides in dust on food or via transfer from hand to mouth.

The importance of the above pathways depends on the details of each specific situation, and the control options available, as discussed below.

3.2 Radiation Dose Limitation in Design and Operation of the Ambassador Open Pit, Leach Plant, and ISR Wellfields and Strip Plant

The mineralised material as mined is considered to be in the range 600 to 800ppm U_3O_8 initially, rising periodically to 1,300ppm as the mine progresses. There will be associated and varying base metal content, being (at various times) copper, nickel, cobalt, zinc, vanadium, scandium, rare earth elements. Contact with solutions of these metals, and dusts containing these metals, will require consideration as occupational hygiene exposure issues.

In terms of uranium content, this is low grade material, which will present to the workers a dose from low level gamma 'shine' and from inhalation of airborne dust containing long lived alpha emitters. Workers' doses will have to be managed so as to be kept "as low as reasonably achievable" (ALARA), and of course, well below the Worker Dose Limit, which is 20mSv per year.

It is expected that the necessary dose control requirements will be relatively straightforward, as they should be no different from, and less onerous than, the dose control requirements at Ranger Uranium Mine in the Northern Territory which has run successfully for the last thirty years.

Dose control in ISR operations will also be low, as evidenced by a decade of operations at the Beverley project in South Australia. The only area in which personal protective equipment (PPE) will be normally required will be the product packing section of the operation (Airstream helmets or similar).

3.3 Gamma (γ) Estimation and Dose Control

Gamma sources will include mine mineralised material benches, and any in-plant radioactive sealed source slurry density gauges (which will be shielded and comply with the relevant design code). There will be limited mineralised material stockpile and thus this will not constitute a significant source.

Gamma doses are controlled, in general, (where needed) by imposing restrictions of occupancy time, by controlling distance from source, or by shielding ("Time, Distance or Shielding"). However, there is no area in the Mulga Rock Project that will require such active controls (other than the sealed source slurry density gauges, as at any other metallurgical plant).

The gamma radiation doses to workers from the mineralised material benches will be small. On the basis of experience, and the technical literature, the author estimates that workers in the pit will accrue well under one third of the annual limit, even before taking into account less than full time occupancy, and (for heavy equipment operators) inherent shielding from equipment.

At the mine, the highest gamma dose rates will be experienced by persons whose work requires them to spend substantial time on foot in the pit, e.g. surveyors, geologists, grade control technicians, blast crews and the like.

In the RIP plant, and in the ISR IX plant, no personnel will be receiving significant gamma doses.

3.4 Committed Dose from Airborne Dust (LLα's), and Control / Design Requirements

Inhalation of long-lived alpha emitters (LLα's) in airborne dust (ore, product, process, or tailings dust) is a potentially important dose delivery pathway, in the mine and leach plant, including product packing, and from dried tailings. Dust release into the air must be minimised.

Dust prevention, enclosure, extraction, or cabin air filtration may be required. As a fallback acceptable for temporary use only, personal protection can be provided via dust masks. Airstream helmets will be required in product packing.

A design aim will be to keep airborne dust well below $1mg/m^3$ in all plant work areas.

Dust control will be assisted by the generally wet or moist nature of the material, and the fact that nearly all processing will be in slurry or solution forms.

However, there is a need for:

(i) effective capture of dust at all dry material transfer and release points in the leach plant

(ii) very good spillage clean-up in the leach plant on a shift by shift basis

(iii) all vehicles in pit to have filtered air conditioned air supply (suggest HEPA filters).

Control of internal 'committed' doses from inhalation of radionuclide-bearing dust is achieved by providing high-standard dust collection and high-standard workplace spill capture and clean-up. Design should be such that respiratory protection should only be required intermittently, as a fallback option. Personal respiratory protection for workers who have to wear PPE for long periods should be Airstream-type helmets or similar.

There will be a need for personal dust monitoring to keep track of worker dust exposures, to determine the effectiveness of controls, and to obtain adequate data for worker dose calculations.

3.5 Physical Design and Operational Issues for Dust Control and Ease of Clean-up

In the mine, haul roads must be watered for dust control. Blasted benches may need to be watered before loading.

Cabins (control rooms, mobile equipment) should be provided with high-quality filtered air (e.g. but not mandatory, HEPA filters).

In the leach plant, sprays need to be designed at dump pockets. Extraction hoods at conveyor transfer points, and at the scrubber feed chute need to be designed with ducting to take the captured dust to scrubbers or baghouses.

Dust collection systems including ducting and baghouses, will be designed to best industry practice as per ACGIH Ventilation Manual or equivalent.

All spillage points, whether wet or dry, need to be designed to allow easy cleaning. If possible, this should always be done wet, by washing to a sump from which spilt slurry can then be pumped back into process. Sumps need to be accessible to skid-steer (‘bobcat’) loaders for dig out.

Ease of maintenance must be provided for in design, by ensuring access for forklifts or (if size demands) Franna type cranes to all pumps, motors etc.

Access under thickeners for bobcats (for clean-up) and short-mast forklifts (for maintenance) sets minimum clearance heights.

As an operational rule, all dry and wet spillages in leach plants and in ISR recovery plants must be cleaned up / washed down every shift.

3.6 Dose Delivery from Ingestion and (Insignificant) Skin Absorption

These two minor dose pathways will essentially be negligible. They will be controlled by ensuring cleanliness of eating areas (crib rooms) and of offices and change rooms, and by requiring that workers have good standards of personal hygiene, including washing of their hands and face before eating and drinking, and showering at the end of each shift. In addition, there should be control by limiting skin contact, and by requiring washing after contact with mineralised material or process material and by covering all cuts and abrasions.

Note that these responses are needed also for addressing the chemical dermal risk associated with base metals and with contact with acid and other irritant solutions.

Layout of plant, plant offices, and mine offices will be such as to require all egress be through shower facilities.

All eating areas must be supplied with hand wash basins outside the entrance (it is not acceptable to use the same basin as that where tea / coffee and meals are prepared).

Self-check alpha probes should be set up in all crib rooms and change rooms.

3.7 Equipment Contamination Control

All releases of equipment from site will be subject to contamination clearance checks. Site layout will 'funnel' vehicles and equipment through wash pad and checkout areas.

3.8 Inhalation of Radon Decay Products (Radon Daughters, RnD)

This pathway will be only of minor importance for the Mulga Rock Project. Radon daughter dose is only of importance when workers are in close proximity to large masses of radon-generating material, in enclosed, unventilated spaces, such as in underground mine stopes or drives, where very specific ventilation design rules must be in place for the control of RnD.

The large open pits which are envisaged within this project, will indeed release radon, but will also be very well naturally ventilated. A generation of operational experience at Ranger Uranium, and at other uranium projects, has shown that even in still air and atmospherically stable conditions, there is still substantial air movement generated by heavy machinery, giving adequate dilution and consequent reduction of RnD levels.

Occupational and environmental radiation monitoring has been ongoing during drilling operations over the last two years. The data generated will be useful for ERMP and BFS purposes.

4. REGULATORY REGIMES AND COMPLIANCE REQUIREMENTS

In Australia, radiation is regulated by State regulatory agencies, which follow codes prepared by the Commonwealth agency, ARPANSA (Australian Radiation Protection and Nuclear Safety Agency). ARPANSA in turn follows international best practice as defined by the International Atomic Energy Agency (IAEA) and the International Commission for Radiological Protection (ICRP). The specific ARPANSA radiation codes which will apply are the Code of Practice on Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing, 2005, and the Code of Practice for Safe Transport of Radioactive Materials 2008 (which directly follows the IAEA Transport Regulations).

In WA there are radiation control requirements laid out in the Mines Safety and Inspection Regulations at Part 16. Additionally, the WA Radiation Safety Act controls licensing of sealed industrial gauges, and the Radiological Council has an advisory role with the DMP.

The Mines Safety and Inspection Regulations requirements are expanded upon via a series of 'NORM Guidelines' which do not have legislative power, but should be referred to. There will be a requirement to obtain a 'Licence to Operate' under state legislature. The conditions on the licence will need to:

(i) show compliance with the ARPANSA Mining and Mineral Processing Code referred to above; and

(ii) undertake to report formally via annual report.

The main requirement of the Code of Practice is that the proponent must develop a Radiation Management Plan (RMP) and a Radioactive Waste Management Plan (RWMP), to be approved by the regulator.

The Commonwealth level of government exercises control via its requirement for an Environmental Impact Statement, under the EPBC Act. The EIS will require an overview of radiation (estimates of doses, how control will be exercised, outline of RMP and RWMP).

The EIS, and in more detail, the RMP and RWMP, will need to address dose control by design, as well as describing operational controls. The EIS, and the RMP / RWMP, and the Company's description of how it intends to apply the Code in its Request for Approval are thus key documents required for Commonwealth and State approvals.

The material in the RMP will have to be developed in some detail, in draft form at least, for insertion into or reference by the BFS (because it will have significant cost implications) and for reference by the EIS (because it will be needed to support the EIS assertion of controllability).

Note that the present exploration activities operate under a simple RMP, specifying the present monitoring regime and waste disposal instructions.

5. OCCUPATIONAL HYGIENE

The occurrence of several base metals, in soluble form, in the mined material and in the leach plant (and as product) will require a rigorous overview of occupational hygiene exposures. This will include a review of MSDS information from analogous materials and solutions and a close review of both monitoring and PPE requirements. Occupational health and safety requirements will be typically similar to those seen in modern processing facilities.