Appendix K – Radiological considerations for the Verdant Minerals Ammaroo Phosphate deposit

VERDANT MINERALS

Radiological Considerations For The Verdant Minerals Ammaroo Phosphate Deposit

Technical Note

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1. INTRODUCTION

Verdant Minerals ("the company") is proposing the development of the Ammaroo phosphate deposit in the Georgina Basin in the Northern Territory.

Phosphate deposits are known to be associated with elevated concentrations of radionuclides, including uranium and thorium. Consequently, the company has characterised the uranium and thorium concentrations and compared to recognised classification criteria, to determine whether the material requires additional controls for the purposes of radiation protection. In addition, the company has conducted a radiological impact assessment on the material.

A summary of the assessment is provided in this technical note.

2. BACKGROUND

The International Atomic Energy Agency (IAEA), notes that the phosphate industry is one of several minerals related industry sectors that may require radiation protection measures (IAEA 2013). The need for control is based on an understanding of the radiological characteristics of mined materials. Even if there are radionuclides present in elevated concentrations, the IAEA strongly recommends that any controls be commensurate with the actual radiological risks. This is encapsulated in the principle of a "graded approach to regulation" that underlies the IAEA framework for protection (IAEA 2007).

The recognised method for conducting this assessment involves;

- characterisation of the materials and
- assessment of impacts from potential exposure pathways.

The IAEA also notes that material containing less than 1Bq/g should not be subject to regulation (IAEA 2004) and this is based on average concentrations of radionuclides (IAEA 2006).

When making an assessment against the radionuclide concentrations, it is usual to consider the activity concentration of the head of the main decay chains, when it can be assumed that the materials are in secular equilibrium.

The empirical relationship are as follows;

- 80ppm uranium is equivalent to 1Bq/g (natural uranium)
- 246ppm thorium is equivalent to 1Bq/g (natural thorium).

(Note that analytical results are usually reported as uranium oxide ppm (U_3O_8). To convert an analysis result reported for U_3O_8 into a pure radionuclide, in order to compare to the IAEA criteria, then the U_3O_8 figure is multiplied by 0.85. This is because uranium makes up approximately 85% of mass of the U_3O_8 compound.)

3. CHARACTERISATION OF THE AMMAROO ORE AND WASTE ROCK MATERIALS

The company has undertaken extensive geological sampling and analysis of the ore and overburden materials.

35,834 samples from the entire 40km long resource were analysed for uranium and gave a mean uranium content 22.7 ppm U_3O_8 (for material containing more that 10% P2O5) and a mean of 16.9 ppm U_3O_8 in overburden. This is equivalent to 0.24 Bq/g of natural uranium in ore and 0.18 Bq/g of natural uranium in overburden. Both of these figures are well below the IAEA criteria for radioactive materials of 1Bq/g (IAEA 2004).

From the samples to be mined in the first 30 years, short sections of only three geographically separated drill holes returned results greater than 80 ppm U_3O_8 (for material containing more that 10% P2O5), being 82.5, 94.3 and 120.5 ppm U_3O_8. When mined, these would be diluted to well below 80ppm.

An analysis of 229 samples from the area to be mined in the first 30 years gave average thorium concentrations of 12ppm. This is equivalent to 0.05Bq/g.

The combined uranium and thorium content therefore does not exceed 1Bq/g and remains below the IAEA criteria for definition as a radioactive material.

The company undertook a literature review of uranium content of other phosphate deposits. The study showed that the Ammaroo deposit contains a lower uranium concentration that most other recognised deposits in the world.

4. RADIOLOGICAL IMPACT ASSESSMENT

Although the ore and overburden is not considered to be radioactive and is therefore not subject to regulations for the purposes of radiological control, the company conducted a radiological impact assessment. This involved a high-level assessment of the potential doses to workers from the following radiological exposure pathways;

- Irradiation by gamma radiation
- Inhalation of dusts containing radionuclides
- Inhalation of the decay products of radon 222 and radon 220

Impacts due to the presence of uranium in the final product are considered to be beyond the scope of this technical note.

4.1 Gamma

The company conducted a recent gamma radiation survey across the top of the ore deposit and identified an average gamma radiation level of 0.07µSv/h, with a maximum of 0.17µSv/h. These levels are consistent with natural background levels found elsewhere in Australia. (Note that ARPANSA quotes an average radiation dose of 0.6 mSv/y from natural background gamma radiation for Australia, which equates to a gamma dose rate of 0.07 µSv/h).

As a rule of thumb, for a material containing approximately 1Bq/g, a gamma doserate of approximately 0. 4µSv/h is generated. For the Ammarro deposit, which contains approximately 0.3Bq/g, the estimated average gamma doserate 0.12µSv/h.

If it is assumed that a worker will work 2,000 hours per year on this material, the maximum unprotected gamma dose would be 0.24mSv/y. It is more likely that potential gamma doses will be on average much lower, due to workers not being exposed to maximum levels all the time. In addition, equipment operators are shielded by the mass of their equipment which therefore results in lower exposures in practice.

It is expected that worker gamma doses will be less than 0.1mSv/y.

4.2 Dust Inhalation

For assessment purposes, an average exposure concentration of 3mg/m^3 has been used. This figure has been quoted in other assessments and appears to be conservative in practice. However, it has been used for understanding the potential impacts from inhalation of dusts.

Based on dust levels of 3mg/m^3 and radionuclide content of 1Bq/g for each of the uranium and thorium decay chains, together with an inhalation rate of 1.2 m^3/h and a full year exposure (of 2,000 hours per years), the radionuclide in dust intake can be determined. The calculated dose is less than 0.1mSv/y based on the ICRP inhalation dose factors (ICRP2011).

4.3 Radon Decay Product Inhalation

Given the low levels of uranium and thorium present in the ore and overburden, it is expected that the potential emissions of radon 222 from the uranium decay chain and radon 220 from the thorium decay chain (also known as thoron) will be negligible and indistinguishable from natural background levels.

Consequently, the potential exposures are considered to be negligible.

5. MANAGEMENT CONSIDERATIONS

The impact assessment shows that potential radiation exposure are very low as would be expected. There are no special controls required for the purposes of radiation protection. General good practices and health and safety requirements (such as dust controls) will be more than adequate for ensuring that potential workers doses remain negligible.

However, the company will aim to verify that the conclusions of this assessment are correct and demonstrate that potential impacts are negligible. To this end, the company has committed to the establishment of a passive gamma, radon and thoron monitoring network. This will consist of 4 environmental monitoring sites (N, S, E and W of the main project area) with passive detectors that will be changed out every three months.

It is anticipated that monitored stations will be installed in a timely manner in order to gather at least one year of pre-operational baseline line radon and gamma baseline data.

6. CONCLUSIONS

In accordance with the criteria for a radioactive material outlined by the IAEA (IAEA 2004), the Ammaroo ore is not considered to be radioactive and therefore not subject to regulatory control for the following reasons;

- Combined uranium and thorium concentrations are less than 1Bq/g, averaging approximately 0.3Bq/g
- Occupational doses (above natural background) are calculated to be less than 1mSv per year.

7. REFERENCES

IAEA 2013 Radiation protection and management of NORM residues in the phosphate industry, Safety reports series, no. 78, IAEA, Vienna (2013)

IAEA 2007 Assessing the Need for Radiation Protection Measures in Work Involving Minerals and Raw Materials, Safety Reports Series No. 49, IAEA, Vienna (2007).

IAEA 2004 Application of the Concepts of Exclusion, Exemption and Clearance Safety Guide IAEA Safety Standards Series No. RS-G-1.7

IAEA 2006 Assessing the need for radiation protection measures in work involving minerals and raw materials. — Vienna, International Atomic Energy Agency, 2006

ICRP 2011 Compendium of Dose Coefficients based on ICRP Publication 60 ICRP Publication 119, 2011