DZP – PAC ASSESSMENT RESPONSES

INTRODUCTION

The aim of this technical note is to address a radiation related recommendation in the Planning Assessment Commission (PAC) assessment of the DZP project. The recommendation is:

- Recommendation 23: Calculations for worker and public exposure to be updated to take account of all potential pathways nominated in ARPANSA Safety Guide prior to determination of the application.

In this technical note, the recommendation is addressed in two parts as follows:

- Dose Assessment to Mine Operators
- Dose Assessment Taking Into Account the ARPANSA Pathways

MINE OPERATOR DOSES

Background

The PAC noted that the radiation assessment for mine operators presented in the EIS did not include potential impacts from ore contained in the walls of the open cut mine and it was requested that a further assessment be conducted. This is presented below.

It should be noted that when making dose estimates, it is appropriate to be conservative in assumptions about the exposure scenarios. If the conservative assumptions provide dose estimates that are low (compared to the recognised limits), then more detailed estimates are not necessary. It is usual to conduct monitoring during actual operations to then confirm the original estimates.

The assumption for the scenario outlined in the EIS was that the open cut mine walls would be in inert material because the assessment was conducted at a time when the pit was at its maximum size and therefore at the point when overall emissions would be highest. To revise the assessment to include the situation where the walls were in ore, also requires the assessment to consider a smaller mine, which would itself be a smaller source of emissions.

However, for the purposes of this assessment, and to provide an absolute maximum it has been assumed that the full size open cut mine has walls that contain ore (at the average uranium and thorium grade for the ore body).

Exposure Pathways

The main radiation exposure pathways assessed for mine operators were;

- Irradiation by gamma radiation
- Inhalation of the decay products of radon
- Inhalation of radionuclides in dust.

The implications of assuming that the walls of the mine are in ore are shown for each of the exposure pathways as follows.

Gamma Radiation

No impact to the mine operator dose assessment.

For the EIS, it was originally assumed that mine operators were constantly exposed to mineralised material, therefore there is no change to mine gamma dose estimates.

Inhalation of Radionuclides in Dust

No impact to the mine operator dose assessment.

For the EIS, it was originally assumed that all dust in the mine is from mineralised material. In addition, the walls would not be standalone dust sources as would be no ongoing mechanical activity associated with the walls and therefore no generation of dust.

Therefore, there is no change to mine operator inhalation dose estimates (from radionuclides in dust).

Inhalation of the Decay Products of Radon

The method used for assessing the inhalation dose from decay products of radon uses the surface area of the mine and a radon emission rate from the exposed mineralised material. The radon emission rate (in $Bq/m^2/s$) is multiplied by the surface area (in m^2) to provide a measure of the amount of radon entering the mine void (in Bq/s).

For the EIS radiation dose estimate, the following criteria were used;

- Maximum open cut size – 40.3 Ha
- Depth of pit – 55m

This gives an emission surface area of 403,000m^2, which is the size of the floor of the mine.

If the walls are to be included, then the additional surface area needs to be calculated. If it is assumed that the pit is a square, then the surface area of the walls can be calculated by taking the square root of the open cut size, multiplying by the depth and then multiplying by four (to account for each of the four walls). This gives a surface area of approximately 140,000m^2, which is approximately 35% higher surface area than just the base of the open cut mine.

From a dose estimate perspective, this represents an increase in mine operator dose of approximately 0.002mSv/y (for inhalation of Rn220 decay products) and 0.007mSv/y (for inhalation of Rn222 decay products).

This does not change the total mine operator dose estimate provided in the EIS of 2.3mSv/y.

ARPANSA EXPOSURE PATHWAYS

Background

ARPANSA (ARPANSA 2008) (referred to as the "safety guide" in this document) provides general guidance on potential radiation related issues associated with NORM. In section 3.2 of the safety guide, a full range of potential exposure pathways are provided.

For the EIS, the radiation assessment was conducted by assessing the doses for workers and the public from only the main exposure pathways. Based on other radiation impact assessment provided in other EIS documents, the main exposure pathways were determined to be;

- Irradiation by gamma radiation
- Inhalation of radionuclides in dust
- Inhalation of the decay products of radon.

This section assessed other exposure pathways as recommended by the PAC review.

Ingestion Pathway

The International Commission on Radiological Protection (ICRP) has published factors that can be used to assess the potential dose impacts from intake of radionuclides (ICRP 1995). Using these factors and the radionuclide composition of the ore, it is possible to estimate potential ingestion doses for various scenarios.

The dose from the ingestion exposure pathway is usually considered to be very low for workers because operations have strict hygiene practices, such as changing into work clothes and showering at the end of shift, washing facilities at the entrance to all clean areas (offices, lunchrooms) and training for workers on the importance of good hygiene practices. Therefore there are a number of precautions in place to minimise the potential for ingestion of materials.

Using the ICRP factors (ICRP 1995), it has been calculated that a worker would need to ingest approximately 3kg of ore to receive the occupational annual dose limit of 20mSv/y.

For the public, the EIS Specialist Consultant Study - Air Quality and Greenhouse Gas Assessment, has modelled dust deposition at the closest privately owned residences (see table 24 of the consultant's report). It shows that the highest deposition rate at these locations is $0.26 g/m^2$/month. Based on 15 years of operation, this amounts to a total deposition of $46.8 g/m^2$ of operational dust. If it is assumed that the dust is only ore dust, and mixes in the top 10mm of soil, then the change in radionuclide content of the soil can be calculated.

The calculations show that after 15 years of deposition of dust from the operations, an adult member of the public would need to consume approximately 36kg of soil to receive the public dose limit of 1mSv/y. (Note that the US EPA quotes an annual "soil intake" for an adult of approximately 30g per year.) For a child, the calculations indicate that an intake of approximately 6kg of soil would lead to an annual dose of 1mSv/y, (note that the US EPA quotes an annual soil intake for a child being also approximately 30g per year).

Although it is unlikely that any soil will be inadvertently consumed by the public at the operations boundary, it is possible that fruit and vegetables could be grown at these locations and the potential dose from deposition of radionuclides from the operation be calculated. This calculation uses conversion factors and methodology provided by the IAEA (IAEA 2010). Using the radionuclide in soil concentrations and an assumed consumption rate of 30kg/year of each of non-leafy fruit and vegetables, leafy fruit and vegetables and root vegetables, the annual ingestion dose is calculated to be approximately 0.01mSv/y.

For consumption of water from rainwater tanks, the estimated doses can be calculated as follows;

- Determine the average annual rainfall (see table 11 of Specialist Consultant Study - Air Quality and Greenhouse Gas Assessment)
- Determine the average annual operational dust deposition (0.26g/m^2/month, giving 3.12g/m^2/y)
- Assume a collection area for rainwater (assume approximately 50m^2)

Therefore total volume of rainwater collected in one year is 500mm by 50m^2, giving 25m^3 of water.

The total amount of dust deposited in one year in the collection area is 3.12g/m^2 by 50m^2, giving 156g, giving a concentration of dust in the rainwater tank of 6.24g/m^3.

If it is assumed that all deposited dust is ore, then the radionuclide concentration can be calculated.

For an annual water consumption of 1m^3 of water per year (just over the recommended 2 litres per day), and all radionuclides evenly distributed within the drinking water (and have not settled to the bottom of the tank), then the total dose as a result of ingestion of radionuclides from deposition in rainwater tanks from the operation is approximately 0.04mSv/y.

External Exposure

For NORM and NORM management direct exposure or external exposure, involves radiation exposure from outside of the human body. This usually occurs from gamma radiation. However, it is also possible for beta radiation to be an external source of radiation. Alpha radiation is not considered to be an external source of radiation exposure because it does not penetrate the dead skin layer.

Usually, gamma radiation is the most important source of external radiation and needs to be considered when there are large sources of radioactive material that are close to people. The amount of gamma radiation that is emitted depends upon both the concentration of radionuclides in the overall host material and the properties of the host material.

For gamma radiation, the intensity of gamma radiation from a material reduces with distance from the material. For a point source, the rate of reduction is inversely proportional to the distance squared (also known as the inverse square law). For area sources, it is usual to approximate the rate of reduction in intensity to the inverse of the distance.

For smaller sources of gamma radiation, such as the amount found on contaminated equipment or from dust deposition, the gamma dose rate is very small.

In the EIS, the gamma dose for workers was calculated using recognised factors for determining the gamma dose rate based on the uranium and thorium content of mineralised materials. The factors are based on the assumption that the exposure comes from an "infinite plane and infinitely thick" slab of mineralised material and that the exposed person is one meter from the slab. For the EIS, these factors were used, together with an exposure time of 2,000 hours per year. It can be seen that exposure based on the large sources will dominate over smaller sources and therefore, the exposure from smaller sources, as identified in the ARPANSA external pathways, will be less than that calculated in the EIS.

For the public, the gamma exposures were assumed to be negligible and the main reason for this was that the larger sources of radioactive materials would be contained well within the lease boundary.

The potential external doses from the ARPANSA external pathways noted by the PAC and the assessments are as follows.

Direct exposure to radionuclides in residue or equipment or plant surfaces

The direct exposure to radionuclides in residues has been taken into account for workers and the public in the assessment provided in the EIS. For workers, this occurred by considering different workgroups and their exposure scenarios. For the public, the stockpiles of residues are well within the project boundary, resulting in negligible exposure (see discussion in this section).

For radionuclides in equipment or on plant surfaces, the external exposure for workers is taken into account through the gamma dose estimates for the different work areas. The component of the overall gamma dose from material in equipment or on plant surfaces is low compared the direct exposure from large quantities or ore or processing materials. For the public, the external radiation from radionuclides in equipment and on plant surfaces results in negligible exposures because these are well within the restricted access area and away from areas occupied by the public.

Direct exposure to radionuclides on the ground surface

Using the WISE radiation dose calculator software (WISE 2015), it is possible to model the gamma doserate from a large area of material containing radionuclides. An assessment was conducted and it was assumed that ore was spread over a 100m by 100m area to a depth of 1mm and that a measurement was taken in the middle of the area at a height of 1m above the ore. The calculated dose rate was 0.05µSv/h, which is similar to existing background levels. If the depth of the ore is increased to 1cm, then the doserate increases to approximately 0.42µSv/h.

The radiation from the thin layer of material would be indistinguishable from natural background levels and the radiation from the 1cm layer indicates that spillages should be prevented or cleaned up to minimise gamma build up. Clean up is a standard operational practice.

Direct exposure from radionuclides in waste rock piles from mining operations

The location of waste rock stockpiles is well within the restricted access mine lease area with no public access. As noted above, the potential gamma exposure at the mine lease boundary is proportional to the distance between the source and the receptor.

Using the WISE radiation dose calculator software (WISE 2015), it is possible to theoretically show the reduction in dose rate with distance. For a 100,000t ore stockpile, with an ore density of 2, the dimensions of the stockpile are approximately 50m wide, 50m long and 20m high (giving a volume of 50,000m^3). At 1m from this stockpile, the gamma dose rate is approximately 1.8µSv/h. At 50m, the gamma dose rate is calculated to be 0.08µSv/h, consistent with natural background levels.

Direct exposure from material deposited on the skin

The direct dose from deposition of radioactive material onto bare skin was calculated using the VARSKIN skin contamination dosimetry software (VARSKIN 2015). The conservative exposure scenario was for a person having their uncovered arms and face contaminated with a 1mm layer of ore dust. If the person was exposed for a full year (24 hours a day) in this way, then their total dose was calculated to be approximately 1mSv. However, this situation is highly unlikely and it is more likely that a worker may be exposed to dust as described.

If it is assumed that worker is exposed to deposited dust on their exposed skin for a full work year (2,000 hours), then the calculated dose is 0.2mSv/y (compared to the annual dose limit of 20mSv/y).

Direct exposure from radionuclides in landfill

DZP is not intending to dispose radioactive material into a publicly accessible landfill. Therefore the potential dose is non-existent.

SUMMARY

This document has provided an assessment of the potential radiation exposures from additional exposure pathways. The assessment shows that the doses from these pathways will be very low to negligible and confirm that the main exposure pathways assessed in the EIS provide an accurate estimate of potential doses to workers and the public.

REFERENCES

ARPANSA 2008	Safety Guide - Management of Naturally Occurring Radioactive Material (NORM) 2008, Radiation Protection Series 15
ICRP 1995	ICRP Publication 72, Age Dependent Doses to the Members of the Public from Intake of Radionuclides - Part 5 Compilation of Ingestion and Inhalation Coefficients, 1995
IAEA 2010	IAEA Technical Report Series 472, Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Terrestrial and Freshwater Environments 2010
WISE 2015	http://www.wise-uranium.org/rdcx.html?src=v&shn=0)
VARSKIN 2015	http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6918/r2/