RADIATION PROTECTION IMPLICATIONS FOR THE NORTH RANGER MINE

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INTRODUCTION

The North Ranger ore deposit is located approximately 20 kilometres north of the existing Ranger mine and mill and 250 kilometres east of Darwin in the Northern Territory of Australia.

The proposed mining operation will use "open stoping" as its preferred method for recovering the ore; subsequently the ore will be transported to the existing Ranger mill for processing.

The Radiological assessment of an underground uranium mine is complex; it needs to assess the radiation exposure from three different pathways, namely gamma ray, radon progeny and radioactive dust exposure. Of the three pathways the assessment of radon progeny exposure is by far the most complex.

At the North Ranger mine radon progeny exposure has been minimised by good ventilation practice and is the least significant of the three exposure pathways.

Gamma radiation is the most significant exposure pathway and this is due to the grade of ore being mined and the mining method.

There are two major phases to the mine development (Case 1 and Case 2 - 600 000 and 900 000 tonnes per annum respectively) and therefore two distinct radiological assessments have been made in line with the mine ventilation and production schedule.

RADON PROGENY MODEL

In ventilating a uranium mine the knowledge of the distribution of radon progeny throughout the ventilation system is essential. The major source of radon gas into the air is from the walls, floor and roof as the air travels down the drives. In the ventilation model the width of the ore intersection for each airway is entered as well as the estimated uranium ore grade. This was achieved by overlaying the ventilation design plans and sections with the geological block model and where any development intersected ore greater than 0.05 % U_3O_8, ore grades and widths were calculated. An emanation rate of 49 Bq $m^{-2}s^{-1}$ per % U_3O_8 was used (2).

The model calculates the average radon emanation rate, the air transit time, and the average radon progeny concentration for each branch, finally the average radon progeny concentration was calculated for each worker category. Full details of the radon progeny model can be found in (3).

GAMMA RAY DOSE RATE MODEL

The theoretical calculation of gamma exposure rates for a rectangular tunnel was used. The various elements such as attenuation of gamma ray by shields and build-up of gamma ray's due to a broad beam source (ore) and thick shields (waste rock on the floor and shotcrete on walls and roof) were considered.

The theory shows that geometry is critical to the exposure rates calculated. However, the theory can not take into account the non-uniform nature of the ore in a tunnel and the shielding provided by machinery (4). It appears that theoretical gamma dose rate models may overestimate the actual dose rate by a factor of about two.

This study assesses the theoretical model "Gamma Model A" and a practical model "Gamma Model B" that uses a dose rate of 50 μSv h^{-1} / % U_3O_8 (4).

Gamma Model A uses theoretical calculations (5), it derives the exposure rate per unit solid angle in an orebody and gives equations for calculating the solid angle subtended by various surface slopes. The resulting theoretical gamma dose rate was 109 μSv h^{-1} / % U_3O_8.

DUST MODEL

The literature survey by Leach (6) showed that for 0.1 per cent uranium ore grade, the typical long-lived alpha activity is, at worst, 0.05 Bq m^{-3}. Similar results have emerged at Olympic Dam, a modern copper/gold/uranium underground mine.

To calculate the effective dose due to the inhalation of uranium ore dust, an average long-lived alpha dust concentration of 0.1 Bq m^{-3} was assumed. This figure was extrapolated from data from Olympic Dam. It is recognised that the actual dust concentrations will vary greatly depending on locality and activity.

WORKPLACE OCCUPANCY

For the purpose of calculating radiation doses to workers it has been found useful to group various workers into categories. This process assists in the administration of radiation protection practices and dose assessments. Five major categories have been determined with these categories being further broken down into various work functions. The locations which the various worker categories occupied during a shift are divided into three specific work place areas, namely high, medium and low grade areas (0.45 %, 0.13 % and 0.02 % U_3O_8 respectively).

DOSE ASSESSMENT

The dose assessment model was developed to estimate likely doses that may be received by the various worker categories.

For each worker category the percentage of the effective hours worked that was subject to shielding were estimated together with a shielding factor. Three forms of shielding were included in the model: equipment shielding, work place shielding due to waste rock on the floor and shotcrete on the walls and roof of ore drives, and, thirdly, the attenuation of dust provided by the air-conditioning on the various types of mobile equipment.

The dose assessment model uses the following shielding factors:

Equipment shielding for gamma	-	50 %
Equipment shielding for dust	-	50 %
Workplace shielding for gamma	-	57 %

The model gives individual work function dose estimates as well as average dose estimates for the five other category groupings.

Table 1 gives the estimated doses for the various work categories using the Gamma Models A and B for Case 1 and Case 2 and the various shielding combinations.

RESULTS AND CONCLUSIONS

Table 1 shows that workers involved in development and supervision receive the highest doses. It is likely that the practice of shielding afforded to the development crews will be less than that for production workers because of the work they perform. In the same way, supervisors will receive higher doses as they experience less equipment shielding. However, when shielding is applied to the high grade cross-cuts to attenuate gamma rays it is possible to reduce the predicted radiation doses to all work categories.

For development and production drillers in particular, advances in equipment technology permitting remote or automatic drill operation may be feasible in the future and would further reduce radiation levels.

If the ventilation design principles are adhered to then the exposure to radon progeny will be low.

A breakdown of the three components of the dose received by development and production categories can be seen in Table 2.

By designing the ventilation system to provide fresh air to each work place as quickly as possible and then exhaust the air, radon progeny exposure is minor.

The gamma radiation is by far the most significant exposure pathway and this is primarily due to the grade of the ore and the mining method. It is therefore necessary to attenuate the gamma rays by use of shotcrete on the walls and roof and waste rock on the floor in the high grade cross-cuts.

Proper management and minimisation of time spent in high grade cross-cuts is critical for the overall control of radiation doses.

With a properly designed ventilation system, shielding, and management control of operator exposure, it is feasible to mine North Ranger in a regime of 20 mSv per annum radiation limit.

Table 1. Radiation Dose Summary.

	Gamma Model A					
	No Shielding		Equipment Shielding Only		Equipment and Work Place Shielding	
Main Work Grouping	Case 1 (mSv)	Case 2 (mSv)	Case 1 (mSv)	Case 2 (mSv)	Case 1 (mSv)	Case 2 (mSv)
Development	21.8	23.3	17.2	18.8	14.3	15.8
Production	20.3	21.5	15.2	16.3	11.2	12.3
Fill & Services	14.5	16.1	13.1	14.8	10.8	12.5
Supervisors	21.7	23.2	19.7	21.1	14.6	16.1
Foreman/Technical	10.9	11.6	10.3	11.1	8.6	9.3
	Gamma Model B					
	No Shielding		Equipment Shielding Only		Equipment and Work Place Shielding	
Main Work Grouping	Case 1 (mSv)	Case 2 (mSv)	Case 1 (mSv)	Case 2 (mSv)	Case 1 (mSv)	Case 2 (mSv)
Development	13.1	14.7	10.4	11.9	9	10.6
Production	12.7	13.8	9.5	10.7	7.7	8.9
Fill & Services	9.7	11.4	8.8	10.5	7.7	9.4
Supervisors	13.2	14.6	12	13.4	9.7	11.1
Foreman/Technical	6.6	7.3	6.3	7	5.5	6.2

Table 2. Gamma Model A Doses Pathways

	Development (mSv)			Production (mSv)		
	Dust	Radon	Gamma	Dust	Radon	Gamma
No Shielding						
Case 1	4.5	1	16.2	4.5	1.6	14.2
Case 2	4.5	2.6	16.2	4.5	2.7	14.2
Equipment Shielding Only						
Case 1	3.5	1	12.7	3.1	1.6	10.5
Case 2	3.5	2.6	12.7	3.1	2.7	10.5
Equipment and Work Place Shielding						
Case 1	3.5	1	9.8	3.1	1.6	6.5
Case 2	3.5	2.6	9.8	3.1	2.7	6.5

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