Case Study Underground Mining

Training Package on Occupational Radiation Protection in Uranium Mining and Processing Industry
Process Description – Mining Methods

• Underlying geology primarily determines the selected mining method
  – Mining method has radiation protection implications

• Room & Pillar Open Stope
  – Horizontal plane mining method that carves out ore & leaves pillars for support; pillars may be mined during retreat from rooms
  – Places workers in orebody with exposure to gamma & radon/radon progeny
Process Description – Mining Methods

• Sublevel Stoping
  – Large vertical stopes are mined by accessing them for blasting from sublevels above a haulage level. Broken ore is collected on the haulage level at the bottom of the stope
  – No additional radiation protection risks, workers mainly out of ore

• Cut & Fill Stoping
  – Ore is cut from below and fill added to floor to gain height
  – Places workers in ore with gamma & radon exposure
Process Description – Mining Methods

• Undercut & Fill
  – Opposite method to cut & fill, ore is cut from floor & fill added above as mining continues
  – Places workers in ore with gamma & radon progeny exposures

• Block Caving
  – Method by which ore is undermined & allowed to cave in on itself. Extracted from bottom of cave
  – Workers removed from ore body
Process Descriptions – Mining Methods

- Non – Entry Mining
  - Equipment is setup for mining & remotely operated, this may be due to health & safety concerns. Best method for mining of high grade deposits.
  - Low exposures to workers due to them being removed from mineralisation.
Design your own underground uranium mine

• Host geology (other mineralisation)?
• Uranium grade?
• Underground mining method?
• Ground support?
• Ventilation?
Model Mine Default Design

- Other associated mineralisation (Copper)
- Low ore grade (~0.05%)
- Room & pillar with retreat “robbing”
- Primary pillar support with secondary shotcreting & cable bolting
- Exhaust and inlet ventilation
Design & Operation – Mine Design

• All underground facilities (offices, rest areas, maintenance workshops, ore handling systems, development drives, etc.) should be situated in un-mineralised zones with fresh inlet air.

• The local geology & location of the ore body typically determines type of mining method
  – Radiation protection is directly affected by mine design
Design & Operation – Ventilation

• Ventilation is the critical element for controlling contaminants & providing fresh air for underground operations
  – Primary control for exposure to radon progeny
  – Required to remove other contaminants (blast fumes, diesel exhaust)
• Mining ventilation design & implementation is a specialised engineering profession
  – Most countries have regulations specific for mining ventilation requirements
  – Radiation protection professionals need to work closely with ventilation engineers & officers
  – Opportunities to merge synergies in monitoring, procedures & other systems should be capitalised
• Local exhaust ventilation requirements in ore handling systems to control Long Lived Radioactive Dust (LLRD)
Design & Operation – Other

• The selection of ground support methods can also aid with radiation protection
  – Shotcrete (shielding) can be used to control areas with high gamma dose rates
• Use of clean fill for road base can minimise gamma exposure
• Where possible water should be used to minimise LLRD
  – Essential for general dust control
• Good housekeeping prevents build up of mineralised material
• Provision of decontamination facilities for personnel & equipment
Determine the Exposure Pathways

• For each stage/exposure group assign a relative level for the importance of the exposure pathway
  – VH-very high, H-high, M-medium, L-low, VL-very low

• Special is for unusual cases such as maintenance
Determine the Exposure Pathways

<table>
<thead>
<tr>
<th>Stage/Pathway</th>
<th>Gamma</th>
<th>Radon Progeny</th>
<th>LLRD*</th>
<th>Special</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ore Handling</td>
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<tr>
<td>Development</td>
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<tr>
<td>Drill &amp; Blast</td>
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<td>Exploration</td>
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<tr>
<td>Underground Maintenance</td>
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<td>Underground Services</td>
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<tr>
<td>Surface Workers</td>
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* LLRD – Long Lived Radioactive Dust
## Model Answers for Exposure Pathways

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</thead>
<tbody>
<tr>
<td>Ore Handling</td>
<td>M</td>
<td>M</td>
<td>L (M*)</td>
<td>M* with poor dust control</td>
</tr>
<tr>
<td>Development</td>
<td>M</td>
<td>M (H*)</td>
<td>L</td>
<td>H* radon progeny in development headings</td>
</tr>
<tr>
<td>Drill &amp; Blast</td>
<td>M</td>
<td>M (H*)</td>
<td>L</td>
<td>H* radon progeny with poor ventilation</td>
</tr>
<tr>
<td>Exploration</td>
<td>M (H*)</td>
<td>M (H*)</td>
<td>L</td>
<td>H* gamma from cuttings, radon progeny from water/poor ventilation</td>
</tr>
<tr>
<td>Underground Maintenance</td>
<td>VL</td>
<td>L</td>
<td>VL</td>
<td>Workshops located in fresh air</td>
</tr>
<tr>
<td>Underground Services</td>
<td>L</td>
<td>M (H*)</td>
<td>L</td>
<td>H* ventilation techs</td>
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<td>VL</td>
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* LLRD – Long Lived Radioactive Dust
What are the potential critical areas for radiation protection?
Model Answers Critical Areas for Radiation Protection

• Inhalation of radon progeny
  – Radon progeny can rise to very high concentrations in poorly ventilated areas
  – Degassing of radon from water can be a significant source term for radon progeny
What Monitoring is Required

- Gamma – which groups need personal monitoring, can monitoring be optimised, do you need real-time assessments?
- LLRD – Sizing, solubility, personal monitoring program for similar exposure groups (SEGs)?
- Radon Progeny – monitoring methods, program to make dose assessment, is personal monitoring required, localised or default Dose Conversion Factor (DCF)?
- Contamination – what are the critical areas, clearance for vehicles & equipment?
- Control Monitoring – what program needs to be developed to monitor controls?
Develop Monitoring Program – Model Answers

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<th>Contamination</th>
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<tbody>
<tr>
<td>Ore Handling</td>
<td>P</td>
<td>Airway Average</td>
<td>SEG</td>
<td>N/A</td>
</tr>
<tr>
<td>Development</td>
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<tr>
<td>Surface Workers</td>
<td>SEG</td>
<td>Surface Average</td>
<td>SEG</td>
<td>N/A</td>
</tr>
<tr>
<td>Locations</td>
<td>N/A</td>
<td>As required to check ventilation</td>
<td>N/A</td>
<td>Visual inspections</td>
</tr>
</tbody>
</table>

* LLRD – Long Lived Radioactive Dust
Model Answers – Monitoring

• Gamma – Personal monitoring for all work groups working in or around ore, selective monitoring for others
• LLRD – Develop SEGs & implement appropriate personal monitoring program
• Radon Progeny – Area based monitoring linked to “airways”, averages to be applied based on occupancy, monitor with assistance of ventilation team, measurements to determine localised or default DCF requirements
• Contamination – Visual inspections of offices, rest areas, ore handling facilities & workshops
• Control Monitoring – Regular inspections of critical ventilation, including local exhaust ventilation
What Controls do you need for your mine?
Model Answers for Controls

• Gamma – High occupancy areas out of mineralisation, shielding (shotcrete, clean fill, vehicles/mobile control rooms, material storage)
• Radon Progeny – Ventilation, minimise sources (water, ore), system for restrictions, enclosed cabins with flow through air conditioning
• LLRD – Local exhaust ventilation at ore handling/transfer locations, use water to suppress dust
• Contamination – Clearance procedures, housekeeping schedules
Dose Assessment

• How do assess gamma for those not given personal monitors?
• What is the DCF for the various areas and what does it consider – radionuclides, particle size, solubility
• How will airways be mapped out & who is best to assist?
• What is the process for selecting SEGs?
Dose Assessment Model Answers

- Workgroup averages for workers without personal monitors
- Assume equilibrium, AMAD of 5 µm & use highest DCF for each radionuclide
  - Only monitor for AMAD & solubility if required.
- Work with ventilation engineers to map out airways which should be fresh → exhaust air pathways
- Discuss tasks with supervisors and operators to determine SEGs & take statistically valid sampling
Key Messages

• Mine design parameters has main influence on exposure pathways.
• All non-critical work & infrastructure placed outside of ore body
• Ventilation is critical and requires professional design & implementation
• Utilise synergies with mine operations to maximise radiation protection (i.e. ventilation, ground control, housekeeping)
• Develop effective monitoring program and review regularly
• Inspect all controls regularly and work with operations to ensure they are maintained
Thank you!