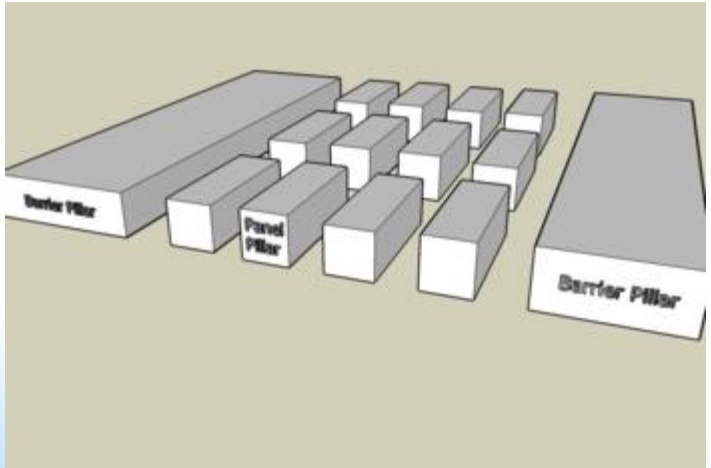
IAEA
International Atomic Energy Agency
Atoms for Peace and Development

Case Study Underground Mining

Training Package on Occupational Radiation Protection in Uranium Mining and Processing Industry

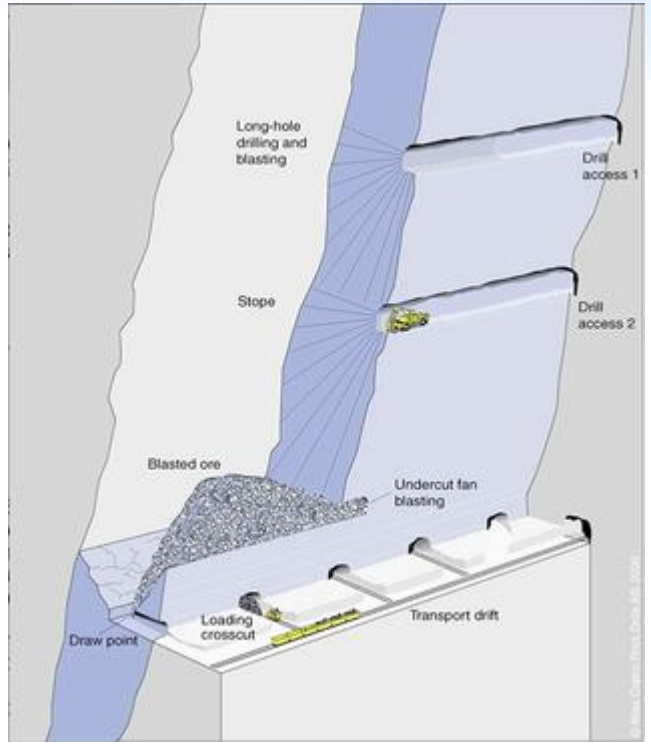
Process Description – Mining Methods

- 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



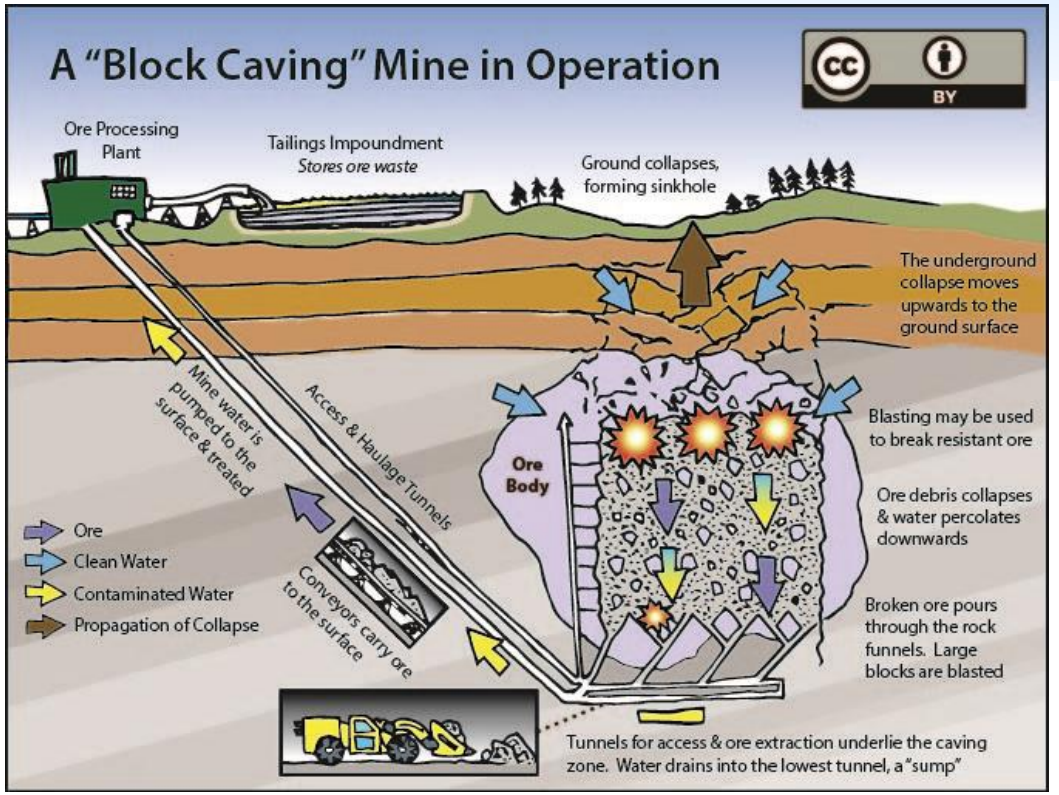
Process Description – Mining Methods

- 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

Stage/Pathway	Gamma	Radon Progeny	LLRD*	Special
Ore Handling				
Development				
Drill & Blast				
Exploration				
Underground Maintenance				
Underground Services				
Surface Workers				

* LLRD – Long Lived Radioactive Dust

Model Answers for Exposure Pathways

Stage/Pathway	Gamma	Radon Progeny	LLRD*	Special
Ore Handling	M	M	L (M*)	M* with poor dust control
Development	M	M (H*)	L	H* radon progeny in development headings
Drill & Blast	M	M (H*)	L	H* radon progeny with poor ventilation
Exploration	M (H*)	M (H*)	L	H* gamma from cuttings, radon progeny from water/poor ventilation
Underground Maintenance	VL	L	VL	Workshops located in fresh air
Underground Services	L	M (H*)	L	H* ventilation techs
Surface Workers	VL	VL	VL	

* LLRD – Long Lived Radioactive Dust

What are the potential critical areas for radiation protection

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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

Stage/Pathway	Gamma	Radon Progeny	LLRD*	Contamination
Ore Handling	P	Airway Average	SEG	N/A
Development	P	Airway Average	SEG	N/A
Drill & Blast	P	Airway Average	SEG	N/A
Exploration	P	Airway Average	SEG	N/A
Underground Maintenance	SEG	Airway Average	SEG	N/A
Underground Services	P	Airway Average	SEG	N/A
Surface Workers	SEG	Surface Average	SEG	N/A
Locations	N/A	As required to check ventilation	N/A	Visual inspections

* 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?

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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

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Thank you!